S
622.25
L3crau
1984
V.3
Comprehensive reclamation of abandoned hard rock mine sites in the urban area of Butte

THIS DOCUMENT
BELONGS TO THE DSL
AMR LIBRARY

Appendices D, E, F, G, and H

COMPREHENSIVE RECLAMATION OF ABANDONED HARD ROCK MINE SITES IN THE URBAN AREA OF BUTTE AND WALKERVILLE, MONTANA

DEPARTMENT OF STATE LANDS

Hydrometrics

MONTANA STATE LIBRARY
3 0864 0014 0755 3

DATE DUE
JUL 1 2 1995
GAYLORD [illegible]
PRINTED IN U.S.A.

NRIS 4/193
2.D.093

APPENDIX D

STATE DOCUMENTS COLLECTION

JUN 09 1995

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

PLEASE RETURN

Digitized by the Internet Archive
in 2014

https://archive.org/details/comprehensivere1984hydr_1

Water Quality Data for Storm-
Water Runoff.

BUTTE STORM SEWER WATER QUALITY DATA

SAMPLING SITE	001	002	003	004	005	006	007	007	008	009
SAMPLE DATE	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83
DESCRIPTION	WARREN AVE.	ANACONDA RD	WARREN AVE.	ANACONDA RD	BUFFALO GL.	BUFFALO GL.	BUFFALO GL.	BUFFALO GL.	MISSOULA GL	MISSOULA GL
DESCRIPTION	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER	STORM SEWER
LAB	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
REMARKS	OUTFALL	OUTFALL	OKLAHOMA AT	COLORADO	ORIGINAL	BUFFALO GL.	MAIN ST.	MAIN ST.	B ST.	ALICE DUMP
REMARKS			GALENA	MINE RUNOFF	MINE RUNOFF	NR RUBY ST.	CULVERT	CULVERT	CULVERT	RUNOFF
DUPLICATE								DUPLICATE		
PHYSICAL PARAMETERS										
SPEC. COND. (UMHOS/CM) LAB	316	247	919	3500	681	171	120	117	122	224
PH LAB	5.5	4.8	2.6	2.3	4.4	5.8	5.5	5.5	5.9	6.4
TURBIDITY (NTU) LAB	420	135	290	950	330	475	170	165	135	58
TOTAL SUSP. SOLIDS	350	120	224	413	284	972	224	264	196	42
COMMON IONS										
CALCIUM (CA)	43.3	24.6	52.1	133	98.8	31.7	15.4	15.7	17.5	30.8
MAGNESIUM (MG)	5.1	5.2	14.2	100	10.8	4.4	1.8	1.9	2.8	5.0
SODIUM (NA)	1.4	3.3	1.6	26.4	1.7	8.1	3.1	3.3	1.6	1.2
POTASSIUM (K)	3.3	0.9	1.9	16.8	1.8	4.0	2.2	1.8	2.5	0.8
TRACE ELEMENTS										
ALUMINUM (AL) TOTAL	9.0	3.9	17.9	143	8.3	9.2	3.0	3.0	2.7	1.3
ALUMINUM (AL) DISS	0.3	0.7	15.8	142	4.1	1.2	0.1	0.2	0.1	<0.1
ARSENIC (AS) TOTAL	0.103	0.077	0.069	8.52	0.134	0.112	0.042	0.040	0.013	0.005
ARSENIC (AS) DISS	<0.005	<0.005	0.007	7.44	<0.005	0.066	0.011	0.010	0.007	<0.005
BARIUM (BA) TOTAL	0.1	<0.1	<0.1	<0.1	0.1	0.2	0.1	0.1	<0.1	<0.1
BARIUM (BA) DISS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
BERYLLIUM (BE) TOTAL	<0.005	<0.005	0.010	0.142	<0.005	0.005	<0.005	<0.005	<0.005	<0.005
BERYLLIUM (BE) DISS	<0.005	<0.005	0.005	0.134	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
BORON (B) TOTAL	<0.1	<0.1	0.1	0.3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) DISS	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CADMIUM (CD) TOTAL	0.054	0.027	0.167	1.010	0.078	0.035	0.011	0.012	0.006	0.009
CADMIUM (CD) DISS	0.046	0.026	0.165	1.000	0.076	0.015	0.005	0.005	0.003	0.007
CHROMIUM (CR) TOTAL	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
CHROMIUM (CR) DISS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
COBALT (CO) TOTAL	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
COBALT (CO) DISS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
COPPER (CU) TOTAL	4.01	3.07	13.6	116	7.90	0.92	0.29	0.30	0.13	0.06
COPPER (CU) DISS	0.62	1.93	13.6	114	6.67	0.87	0.06	0.06	0.04	.06
IRON (FE) TOTAL	9.66	6.31	28.3	442	8.99	15.8	3.53	3.59	3.18	1.10
IRON (FE) DISS	<0.03	<0.03	10.7	414	0.57	2.86	0.09	0.08	0.06	<0.03
LEAD (PB) TOTAL	0.72	0.33	1.18	2.82	0.80	1.76	0.50	0.50	0.49	0.12
LEAD (PB) DISS	<0.01	0.04	0.92	2.72	0.22	0.06	<0.01	<0.01	<0.01	<0.01
MANGANESE (MN) TOTAL	1.26	1.11	4.66	29.2	4.75	2.9	0.83	0.85	1.80	1.36

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED

BUTTE STORM SEWER WATER QUALITY DATA

SAMPLING SITE	001	002	003	004	005	006	007	007	008	009
SAMPLE DATE	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83	10/14/83
TRACE ELEMENTS										
MANGANESE (MN) DISS	1.05	1.05	4.65	28.8	4.34	0.72	0.47	0.47	0.60	1.15
MERCURY (HG) TOTAL	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
MERCURY (HG) DISS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
MOLYBDENUM (MO) TOTAL	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	0.005
MOLYBDENUM (MO) DISS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005
NICKEL (NI) TOTAL	<0.03	<0.03	0.03	0.16	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
NICKEL (NI) DISS	<0.03	<0.03	0.03	0.12	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
SILICON (SI) TOTAL	12.7	5.1	6.7	14.9	9.5	18.5	7.1	7.2	7.9	5.6
SILICON (SI) DISS	4.0	3.3	3.0	9.7	4.0	4.7	2.8	2.8	4.0	3.5
SILVER (AG) TOTAL	<0.005	<0.005	<0.005	0.080	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
SILVER (AG) DISS	<0.005	<0.005	<0.005	0.060	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
STRONTIUM (SR) TOTAL	0.1	0.1	0.1	<0.1	0.2	0.1	<0.1	<0.1	0.1	0.1
STRONTIUM (SR) DISS	0.1	0.1	0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.1
TIN (SN) TOTAL	<0.1	<0.1	<0.1	0.4	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TIN (SN) DISS	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TITANIUM (TI) TOTAL	0.16	0.05	0.10	0.06	0.15	0.13	0.10	0.10	0.13	0.05
TITANIUM (TI) DISS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TUNGSTEN (W) TOTAL	0.3	0.2	0.7	5.6	0.3	0.4	0.1	0.1	0.1	<0.1
TUNGSTEN (W) DISS	<0.1	<0.1	0.6	5.6	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
VANADIUM (V) TOTAL	<0.10	<0.10	<0.10	0.14	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
VANADIUM (V) DISS	<0.10	<0.10	<0.10	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
ZINC (ZN) TOTAL	12.4	7.68	30.2	332	18.3	8.21	2.80	2.85	1.27	2.05
ZINC (ZN) DISS	10.5	7.45	30.2	326	17.8	4.33	1.71	1.75	0.55	1.81

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED

BUTTE STORM SEWER WATER QUALITY DATA

SAMPLING SITE	010	011
SAMPLE DATE	10/14/83	10/14/83
DESCRIPTION	ANSELMO MIN	OUTFALL AT
DESCRIPTION	RUNOFF	EXCELSIOR
LAB	EL	EL
REMARKS	MISSOULA GL	MISSOULA GL
REMARKS	STORM SEWER	STORM SEWER
PHYSICAL PARAMETERS		
SPEC. COND. (UMHOS/CM) LAB	319	311
PH LAB	4.3	6.3
TURBIDITY (NTU) LAB	105	46
TOTAL SUSP. SOLIDS	62	41
COMMON IONS		
CALCIUM (CA)	23.6	39.1
MAGNESIUM (MG)	5.2	7.6
SODIUM (NA)	<0.5	8.2
POTASSIUM (K)	1.3	2.8
TRACE ELEMENTS		
ALUMINUM (AL) TOTAL	4.5	1.1
ALUMINUM (AL) DISS	1.8	<0.1
ARSENIC (AS) TOTAL	0.024	0.008
ARSENIC (AS) DISS	<0.005	0.008
BARIUM (BA) TOTAL	<0.1	<0.1
BARIUM (BA) DISS	<0.1	<0.1
BERYLLIUM (BE) TOTAL	<0.005	<0.005
BERYLLIUM (BE) DISS	<0.005	<0.005
BORON (B) TOTAL	<0.1	0.1
BORON (B) DISS	<0.1	0.1
CADMIUM (CD) TOTAL	0.098	0.011
CADMIUM (CD) DISS	0.097	0.007
CHROMIUM (CR) TOTAL	<0.02	<0.02
CHROMIUM (CR) DISS	<0.02	<0.02
COBALT (CO) TOTAL	0.01	<0.01
COBALT (CO) DISS	<0.01	<0.01
COPPER (CU) TOTAL	6.12	0.38
COPPER (CU) DISS	5.79	0.09
IRON (FE) TOTAL	2.50	0.80
IRON (FE) DISS	0.58	<0.03
LEAD (PB) TOTAL	0.34	0.10
LEAD (PB) DISS	0.10	<0.01
MANGANESE (MN) TOTAL	4.31	1.10
MANGANESE (MN) DISS	4.29	1.02

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED

BUTTE STORM SEWER WATER QUALITY DATA

SAMPLING SITE	010	011
SAMPLE DATE	10/14/83	10/14/83
TRACE ELEMENTS		
MERCURY (HG) TOTAL	<0.001	<0.001
MERCURY (HG) DISS	<0.001	<0.001
MOLYBDENUM (MO) TOTAL	<0.005	<0.005
MOLYBDENUM (MO) DISS	<0.005	<0.005
NICKEL (NI) TOTAL	<0.03	<0.03
NICKEL (NI) DISS	<0.03	<0.03
SILICON (SI) TOTAL	4.8	9.0
SILICON (SI) DISS	3.4	7.3
SILVER (AG) TOTAL	<0.005	<0.005
SILVER (AG) DISS	<0.005	<0.005
STRONTIUM (SR) TOTAL	<0.1	0.2
STRONTIUM (SR) DISS	<0.1	0.2
TIN (SN) TOTAL	<0.1	0.1
TIN (SN) DISS	<0.1	<0.1
TITANIUM (TI) TOTAL	0.03	0.04
TITANIUM (TI) DISS	<0.03	<0.01
TUNGSTEN (W) TOTAL	0.2	<0.1
TUNGSTEN (W) DISS	<0.1	<0.1
VANADIUM (V) TOTAL	<0.10	<0.10
VANADIUM (V) DISS	<0.10	<0.10
ZINC (ZN) TOTAL	30.0	2.78
ZINC (ZN) DISS	29.9	1.87

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER
SAMPLE DATE	06/12/79	07/17/79	07/19/79	07/20/79	07/24/79	08/02/79	09/11/79	09/12/79	09/14/79
LOCATION	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W
LOCATION	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD
DESCRIPTION	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA
DESCRIPTION	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM
LAB	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC
SAMPLED BY	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC
PHYSICAL PARAMETERS									
FLOW (CFS)	0.557	0.11	0.3	0.3	0.423	0.290	0.37	0.28	0.10
PH LAB	4.4	6.8	9.8	7.5	4.3	7.1	3.3	3.4	6.5
TOTAL SUSP. SOLIDS		44							
COMMON IONS									
SULFATE (SO4)	7.80		1490			40	1620	110	90
TRACE ELEMENTS									
COPPER (CU) TOTAL	7.60	0.43	0.17	2.30	8.59	0.12	20.60	18.70	0.16
IRON (FE) TOTAL	94.0	2.15	0.89	17.80	66.50	1.20	169.0	182.00	0.18
LEAD (PB) TOTAL									
MANGANESE (MN) TOTAL		0.87	0.09	14.40	16.40		35.30	35.00	0.62
ZINC (ZN) TOTAL	38.0	1.45	0.28	6.70	30.70	0.18	55.00	56.00	1.30
LOADINGS									
SULFATE (LBS/DAY)	23		2409			63	3231	166	49
COPPER (LBS/DAY)	23	.25	.27	3.7	20	.19	41	28	.09
IRON (LBS/DAY)	282	1.3	1.4	29	152	1.9	337	275	.1
ZINC (LBS/DAY)	114	.86	.45	11	70	.28	110	85	.7

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO. EL = ENERGY LABORATORIES HYD = HYDROMETRICS

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER	CIVIC SEWER
SAMPLE DATE	10/11/79	10/12/79	10/15/79	11/08/79	11/09/79	11/09/79	11/12/79	11/12/79	11/16/79
LOCATION	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W	003N007W
LOCATION	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD	19BAD
DESCRIPTION	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA	ANACONDA
DESCRIPTION	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM	RD STORM
LAB	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC
SAMPLED BY	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC
PHYSICAL PARAMETERS									
FLOW (CFS)	0.460	0.524	0.500	0.4			0.192	0.300	0.5
PH LAB	4.0	4.0	4.8	6.8	7.7	7.8	8.6	7.8	6.8
TOTAL SUSP. SOLIDS									
COMMON IONS									
SULFATE (SO4)				140	70	80	30	270	60
TRACE ELEMENTS									
COPPER (CU) TOTAL	5.23	6.75	22.20	1.62	0.09	1.50	0.07	0.18	0.24
IRON (FE) TOTAL	34.50	78.50	113.00	13.3	0.61	5.45	0.62	1.38	2.05
LEAD (PB) TOTAL									
MANGANESE (MN) TOTAL	10.40	12.70	6.55	2.70	0.09	0.38	0.06	0.10	0.35
ZINC (ZN) TOTAL	18.20	24.30	17.50	4.85	0.12	0.94	0.11	0.32	0.42
LOADINGS									
SULFATE (LBS/DAY)				302			31	437	162
COPPER (LBS/DAY)	13	19	60	3.5			.07	.29	.65
IRON (LBS/DAY)	86	222	305	29			.64	2.2	5.5
ZINC (LBS/DAY)	45	69	47	10			.11	.52	1.1

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO.   EL = ENERGY LABORATORIES   HYD = HYDROMETRICS

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE SAMPLE DATE	CIVIC SEWER 11/21/79	CIVIC SEWER 11/27/79	MISSOULA GULCH 10/18/78	MISSOULA GULCH 10/20/78	MISSOULA GULCH 10/22/78	MISSOULA GULCH 05/20/79	MISSOULA GULCH 07/06/79	MISSOULA GULCH 07/19/79	MISSOULA GULCH 09/12/79
LOCATION	003N007W	003N007W	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W
LOCATION	19BAD	19BAD	23AAA	23AAA	23AAA	23AAA	23AAA	23AAA	23AAA
DESCRIPTION	ANACONDA	ANACONDA	AT SILVER	AT SILVER	AT SILVER	AT SILVER	AT SILVER	AT SILVER	AT SILVER
DESCRIPTION	RD STORM	RD STORM	BOW CK	BOW CK	BOW CK	BOW CK	BOW CK	BOW CK	BOW CK
LAB	AMC	AMC	EPA	EPA	EPA	AMC	AMC	AMC	AMC
SAMPLED BY	AMC	AMC				AMC	AMC	AMC	AMC
PHYSICAL PARAMETERS									
FLOW (CFS)			0.27	0.18	0.17	0.579	0.45	0.35	0.490
PH LAB	6.3	4.1					8.1	7.9	
TOTAL SUSP. SOLIDS	106	174							
COMMON IONS									
SULFATE (SO4)			220	210	270	160	180	150	200
CHLORIDE (CL)			22	22	25				
TRACE ELEMENTS									
COPPER (CU) TOTAL	1.44	12.2	2.4	1.6	2.2	0.24	0.20	0.22	0.24
IRON (FE) TOTAL	14.0	114	2.6	1.1	0.26	0.61	0.16	0.16	0.31
LEAD (PB) TOTAL									
MANGANESE (MN) TOTAL	2.20	18.8						1.55	1.68
ZINC (ZN) TOTAL	3.90	35.0	9.6	9.0	12	3.82	3.45	3.50	3.57
LOADINGS									
SULFATE (LBS/DAY)			320	204	247	499	437	283	528
COPPER (LBS/DAY)			3.5	1.6	2	.75	.49	.42	.63
IRON (LBS/DAY)			3.8	1.1	.24	1.9	.39	.3	.82
ZINC (LBS/DAY)			14	8.7	11	12	8.4	6.6	9.4

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO.   EL = ENERGY LABORATORIES   HYD = HYDROMETRICS

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE	MISSOULA GULCH	KELLEY SEWER	KELLEY SEWER	KELLEY SEWER	WEST JR HIGH	MONT ST STORM	MONT ST STORM	MONT ST STORM	MAG PLANT SEEPAGE
SAMPLE DATE	11/12/79	11/15/79	11/16/79	11/28/79	09/12/79	05/24/79	06/19/79	07/19/79	05/20/79
LOCATION	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W
LOCATION	23AAA	13AAD	13AAA	13AAA	14DDD	24DBB	24DBB	24DBB	24CAB
DESCRIPTION	AT SILVER	NR KELLEY	NR KELLEY	NR KELLEY	GERARD AVE	BUFFALO	BUFFALO	BUFFALO	NR CENTEN
DESCRIPTION	BOW CK	MINE	MINE	MINE	STORM SWR	GL STORM	GL STORM	GL STORM	-NIAL AVE
LAB	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC
SAMPLED BY	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC	AMC
PHYSICAL PARAMETERS									
FLOW (CFS)					0.99			0.004	0.009
TURBIDITY (JTU) LAB						95			
PH LAB	7.8	7.4	9.4	3.1	7.4	7.7	7.5	7.0	
TOTAL SUSP. SOLIDS		38		20		264			
COMMON IONS									
TOTAL HARDNESS AS CACO3						190			
SULFATE (SO4)	290	150	80		210	70	50	30	750
TRACE ELEMENTS									
COPPER (CU) TOTAL	0.20	0.98	0.43	16.2	0.25	0.52	0.37	0.27	7.75
IRON (FE) TOTAL	0.10	8.25	3.85	235	0.17	7.56	2.35	0.37	0.48
LEAD (PB) TOTAL									
MANGANESE (MN) TOTAL	1.10	0.93	0.54	42.5	0.42			0.25	
ZINC (ZN) TOTAL		1.85	1.04	69.5	2.59	0.67	0.86	0.21	32.90
LOADINGS									
SULFATE (LBS/DAY)					1121			.65	36
COPPER (LBS/DAY)					1.3			.01	.38
IRON (LBS/DAY)					.91			.01	.02
ZINC (LBS/DAY)					14			0	1.6

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO.   EL = ENERGY LABORATORIES   HYD = HYDROMETRICS

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE	MAG PLANT SEEPAGE	MAG PLANT SEEPAGE	UNNAMED DRAINAGE	BR-171	KAW AVE	KAW AVE	WEST ROCKER	WEST ROCKER	EAST ROCKER
SAMPLE DATE	05/24/79	07/30/79	04/13/82	04/22/82	05/20/79	09/12/79	05/20/79	09/14/79	09/14/79
LOCATION	003N008W	003N008W	003N008W	003N008W	003N008W	003N008W			
LOCATION	24CAB	24CAB	16C	12ADB	24DAA	24DAA			
DESCRIPTION	NR CENTEN	NR CENTEN	AT I-90	JOSEPHINE	OPEN DITCH	OPEN DITCH	OPEN DITCH	OPEN DITCH	OPEN DITCH
DESCRIPTION	-NIAL AVE	-NIAL AVE	AT ROCKER	MINE	ABOVE KAW	ABOVE KAW	ABOVE	ABOVE	E. ROCKER
LAB	AMC	AMC	EL	EL	AMC	AMC	AMC	AMC	AMC
SAMPLED BY	AMC		NYD	HYD	AMC	AMC	AMC	AMC	AMC
PHYSICAL PARAMETERS									
FLOW (CFS)	0.009	0.028			0.089	0.08	0.375	0.03	0.360
TURBIDITY (JTU) LAB	25								
PH LAB	6.5	6.6							
TOTAL SUSP. SOLIDS	4								
COMMON IONS									
TOTAL HARDNESS AS CACO3	570								
SULFATE (SO4)	750	80			80	1560	30	840	330
TRACE ELEMENTS									
ALUMINUM (AL) TOTAL			0.4	42.6					
ARSENIC (AS) TOTAL			0.014	0.09					
BARIUM (BA) TOTAL			(0.1	0.8					
CADMIUM (CD) TOTAL			(0.001	0.122					
COPPER (CU) TOTAL	7.75	0.06	0.01	4.41	0.09	0.07	0.17	0.06	0.03
IRON (FE) TOTAL	0.48	0.16	0.48	46.6	0.63	0.23	1.12	0.07	0.12
LEAD (PB) TOTAL			(0.01	7.28					
MANGANESE (MN) TOTAL			0.46	25.9		0.15		0.03	0.01
MERCURY (HG) TOTAL			(0.0002	0.0002					
SELENIUM (SE) TOTAL			(0.005	(0.005					
SILVER (AG) TOTAL			(0.005	0.013					
ZINC (ZN) TOTAL	32.9	1.23	0.16	24.8	0.19	0.19	0.17	0.20	0.11
LOADINGS									
SULFATE (LBS/DAY)	36				38	673	61	136	640
COPPER (LBS/DAY)	.38				.04	.03	.34	.01	.06
IRON (LBS/DAY)	.02				.3	.1	2.3	.01	.23
ZINC (LBS/DAY)	1.6				.09	.08	.34	.03	.21

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO.   EL = ENERGY LABORATORIES   HYD = HYDROMETRICS

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE	METRO STORM	METRO STORM
SAMPLE DATE	05/20/79	09/12/79
LOCATION	003N007W	003N007W
LOCATION	19ABC	19ABC
DESCRIPTION	WARREN AVE	WARREN AVE
DESCRIPTION	STORM	STORM
LAB	AMC	AMC
SAMPLED BY	AMC	AMC
PHYSICAL PARAMETERS		
FLOW (CFS)	0.033	0.28
PH LAB		
TOTAL SUSP. SOLIDS		
COMMON IONS		
SULFATE (SO4)	30	110
TRACE ELEMENTS		
COPPER (CU) TOTAL	0.10	18.7
IRON (FE) TOTAL	1.05	182
LEAD (PB) TOTAL		
MANGANESE (MN) TOTAL		35.0
ZINC (ZN) TOTAL	0.05	56.0
LOADINGS		
SULFATE (LBS/DAY)	5.3	166
COPPER (LBS/DAY)	.02	28
IRON (LBS/DAY)	.19	275
ZINC (LBS/DAY)	.01	85

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO.   EL = ENERGY LABORATORIES   HYD = HYDROMETRICS

BUTTE - SILVER BOW STORM SEWER WATER QUALITY DATA

SAMPLING SITE	METRO STORM	METRO STORM
SAMPLE DATE	05/20/79	09/12/79
LOCATION	003N007W	003N007W
LOCATION	19ABC	19ABC
DESCRIPTION	WARREN AVE	WARREN AVE
DESCRIPTION	STORM	STORM
LAB	AMC	AMC
SAMPLED BY	AMC	AMC
PHYSICAL PARAMETERS		
FLOW (CFS)	0.033	0.28
PH LAB		
TOTAL SUSP. SOLIDS		
COMMON IONS		
SULFATE (SO4)	30	110
TRACE ELEMENTS		
COPPER (CU) TOTAL	0.10	18.7
IRON (FE) TOTAL	1.05	182
LEAD (PB) TOTAL		
MANGANESE (MN) TOTAL		35.0
ZINC (ZN) TOTAL	0.05	56.0
LOADINGS		
SULFATE (LBS/DAY)	5.3	166
COPPER (LBS/DAY)	.02	28
IRON (LBS/DAY)	.19	275
ZINC (LBS/DAY)	.01	85

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED
BLANK LINE INDICATES PARAMETER NOT TESTED
AMC = ANACONDA MINERALS CO.   EL = ENERGY LABORATORIES   HYD = HYDROMETRICS

APPENDIX 3

GROVE CREEK SURFACE WATER QUALITY DATA

SAMPLING SITE: GROVE GULCH 1 (ALSO GC1)
GROVE GULCH CR AT LITTLE BASIN CR RD CULVERT

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	7.8	.3	7.4-8.4	9
TOTAL SUSP. SOLIDS	4		4	1
COMMON IONS				
SULFATE (SO4)	75	21.2	60-90	2
TRACE ELEMENTS				
ARSENIC (AS) TOTAL	.021	.032	<.01-<.1	8
CADMIUM (CD) TOTAL	.01	0	<.01	4
COPPER (CU) TOTAL	.022	.013	<.01-.05	10
IRON (FE) TOTAL	.587	.536	.06-1.74	10
LEAD (PB) TOTAL	.013	.005	<.01-.02	4
MANGANESE (MN) TOTAL	.029	.017	<.01-.06	8
ZINC (ZN) TOTAL	.046	.043	.01-.14	10

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

ANACONDA MINERALS - CLARK TAILINGS STUDY UNIT

SAMPLING SITE: ABOVE GROVE GULCH
GROVE GULCH CR APPROX 0.3 MI BELOW GROVE GULCH 1

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	7.3	.3	7.1-7.7	3
TOTAL SUSP. SOLIDS				
COMMON IONS				
SULFATE (SO4)	80		80	1
TRACE ELEMENTS				
ARSENIC (AS) TOTAL				
CADMIUM (CD) TOTAL	.01	0	<.01	2
COPPER (CU) TOTAL	.023	.015	.01-.04	3
IRON (FE) TOTAL	2.983	1.845	1.36-4.99	3
LEAD (PB) TOTAL	.01	0	<.01	2
MANGANESE (MN) TOTAL	1.05	.853	.38-2.01	3
ZINC (ZN) TOTAL	.02	.01	.01-.03	3

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

ANACONDA MINERALS - CLARK TAILINGS STUDY UNIT

SAMPLING SITE: GROVE GULCH 2 (ALSO GC2)
GROVE GULCH CR APPROX 0.4 MI BELOW GROVE GULCH 1

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	7.6	.2	7.2-7.8	7
TOTAL SUSP. SOLIDS	2		2	1
TRACE ELEMENTS				
ARSENIC (AS) TOTAL	.028	.04	<.01-<.1	5
CADMIUM (CD) TOTAL	.01	0	<.01	3
COPPER (CU) TOTAL	.016	.008	<.01-.03	7
IRON (FE) TOTAL	.62	.383	.33-1.47	7
LEAD (PB) TOTAL	.017	.012	<.01-.03	3
MANGANESE (MN) TOTAL	.17	.145	.03-.39	5
ZINC (ZN) TOTAL	.046	.052	<.01-.16	7

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

SAMPLING SITE: GROVE GULCH 3 (ALSO NO. 3 RISER TO OLD DRAIN LINE)
GROVE GULCH CR APPROX 0.5 MI BELOW GROVE GULCH 1

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	7.5	.2	7.2-7.8	7
TOTAL SUSP. SOLIDS	4		4	1
COMMON IONS				
SULFATE (SO4)	85	21.2	70-100	2
TRACE ELEMENTS				
ARSENIC (AS) TOTAL	.093	.176	<.01-.45	6
CADMIUM (CD) TOTAL	.01	0	<.01-.01	3
COPPER (CU) TOTAL	.089	.156	.01-.47	8
IRON (FE) TOTAL	11.249	20.4	.77-56.7	8
LEAD (PB) TOTAL	.06	.07	.01-.14	3
MANGANESE (MN) TOTAL	1.836	1.884	.28-4.7	5
ZINC (ZN) TOTAL	.22	.313	.03-.95	8

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

SAMPLING SITE: GROVE GULCH 4 (SFC RUNOFF; SUSPENDED SEDIMENT REMOVED)
CLARK TAILINGS APPROX 100 FT ABOVE RR EMBANKMENT

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB				
COMMON IONS				
SULFATE (SO4)				
NUTRIENTS				
AMMONIA (NH4-N)				
NITRATE (NO3-N)				
NITRITE (NO2-N)				
KJELDAHL NITROGEN AS N				
TRACE ELEMENTS				
ARSENIC (AS) TOTAL				
CADMIUM (CD) TOTAL	5.67		5.67	1
COPPER (CU) TOTAL	41.6		41.6	1
IRON (FE) TOTAL	9.1		9.1	1
LEAD (PB) TOTAL	.84		.84	1
MANGANESE (MN) TOTAL	3480		3480	1
ZINC (ZN) TOTAL	1750		1750	1

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

SAMPLING SITE: GROVE GULCH 4 (SFC RUNOFF FROM CLARK TAILINGS; NO SETTLING)
CLARK TAILINGS APPROX 100 FT ABOVE RR EMBANKMENT

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	4.3		4.3	1
TOTAL SUSP. SOLIDS				
COMMON IONS				
SULFATE (SO4)				
NUTRIENTS				
AMMONIA (NH4-N)				
NITRATE (NO3-N)				
NITRITE (NO2-N)				
KJELDAHL NITROGEN AS N				
TRACE ELEMENTS				
ARSENIC (AS) TOTAL				
CADMIUM (CD) TOTAL	5.81		5.81	1
COPPER (CU) TOTAL	36.65	10.819	29-44.3	2
IRON (FE) TOTAL	194.45	166.241	76.9-312	2
LEAD (PB) TOTAL	4.12		4.12	1
MANGANESE (MN) TOTAL	1991.5	2246.478	403-3580	2
ZINC (ZN) TOTAL	966	1193.596	122-1810	2

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

SAMPLING SITE: GROVE GULCH 5 (ALSO BELOW GROVE GULCH)
OLD WOOD AND TILE DRAIN OUTLET AT RR EMBANKMENT

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	7.5	.2	7.1-7.9	12
TOTAL SUSP. SOLIDS	4		4	1
COMMON IONS				
SULFATE (SO4)	86.7	5.8	80-90	3
TRACE ELEMENTS				
ARSENIC (AS) TOTAL	.021	.032	<.01-.1	8
CADMIUM (CD) TOTAL	.01	0	<.01	6
COPPER (CU) TOTAL	.023	.014	<.01-.05	13
IRON (FE) TOTAL	1.667	.836	.54-3.4	13
LEAD (PB) TOTAL	.012	.004	<.01-.02	6
MANGANESE (MN) TOTAL	1.737	1.34	.19-3.87	11
ZINC (ZN) TOTAL	.062	.043	.01-.17	13

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

SAMPLING SITE: GROVE GULCH 6 (NEAR TRAILER COURT)
GROVE GULCH CR NEAR INTERSECTION

	MEAN	STANDARD DEVIATION	RANGE	NUMBER OF SAMPLES
PHYSICAL PARAMETERS				
PH LAB	7.6	.4	7.2-8.2	7
TOTAL SUSP. SOLIDS	2		2	1
TRACE ELEMENTS				
ARSENIC (AS) TOTAL	.034	.048	<.01-.12	5
CADMIUM (CD) TOTAL	.01	0	<.01	3
COPPER (CU) TOTAL	.054	.025	.03-.1	7
IRON (FE) TOTAL	.611	.183	.35-.77	7
LEAD (PB) TOTAL	.02	.017	<.01-.04	3
MANGANESE (MN) TOTAL	.998	.945	.22-2.55	5
ZINC (ZN) TOTAL	.849	1.138	.12-2.89	7

ALL QUANTITIES IN MILLIGRAMS PER LITER UNLESS OTHERWISE NOTED. MEAN ESTIMATE MAY BE SLIGHTLY HIGH FOR PARAMETERS WHICH INCLUDE VALUES BELOW THE DETECTION LIMIT. FOR VALUES BELOW THE DETECTION LIMIT, THE DETECTION LIMIT WAS USED IN THE STATISTICAL ANALYSIS.

APPENDIX E

Social and Economic Section of the Comprehensive Reclamation and Engineering Plan for Abandoned Hard Rock Mines in Silver Bow County

Prepared for:

Montana Department of State Lands

Helena, Montana

By:

Joseph E. Kasperick

ECONSULT, INC.

(In Consultation with

Dr. Thomas Lester)

Butte, Montana

January 8, 1984

Table of Contents

Description	Page Number
Introduction	1
Part I, General Social and Economic Characteristics	2
Part II, Socioeconomic Survey	12
Part III, Property Valuations and Housing Characteristics	17
Exhibit 1, Summary of Social and Economic Characteristics, Montana and Silver Bow County	19
Exhibit 2, Graphic Profile of Montana Population by Counties	24
Exhibit 3, Population of Montana and Silver Bow County, 1940 - 1980	25
Exhibit 4, Population of Montana and Silver Bow County, by age, 1980	26
Exhibit 5, Graphic Profile of Public School Enrollment, 1971 to 1976	27
Exhibit 6, Graphic Profile of Public School Expenditures	28
Exhibit 7, Graphic Profile of Per Capita Income: 1976	29
Exhibit 8, Graphic Profile of Property Taxes: 1977	30
Exhibit 9, Graphic Profile of Social Security Beneficaries	31
Exhibit 10, Summary of Economic Characteristics, 1980	32
Exhibit 11, County Population and Employment by Industry, Silver Bow County, 1940 - 1980	33
Exhibit 12, Employment in Anaconda-Deer Lodge, Butte-Silver Bow, and Montana, 1970 - 1983	34
Exhibit 13, Employers, Workers, and Wages in All Major Industries and in the Mining Industry in Silver Bow County, 1950 - 1973	35

Table of Contents, Cont.

Description	Page Number
Exhibit 14, Employers, Workers and Wages in All Major Industries and in the Mining Industry, Montana, 1950 - 1973	36
Exhibit 15, Memorandum from Donald Peoples, Mayor, Butte-Silver Bow, November 4, 1983	37
Exhibit 16, Memorandum from Joseph E. Kasperick and Thomas Lester, November 9, 1983	38
Exhibit 17, Results of Socioeconomic Survey	39
Exhibit 18, Housing Characteristics in Butte-Silver Bow	40

INTRODUCTION

The city of Butte began its glorious history as a gold mining camp in the 1860's. In the 1870's, when the supply of gold began to run out, the mining activity changed to silver and quartz. Copper mining then took over as the prominent industry during the 1880's with the invention of the electric light followed by an increased demand for copper to be used as conductors. From 1880 to 1920 economic expansion continued in the Butte area. A heavy employment growth in the mining industry was experienced along with the development of several new mines and smelters in the area. Following the turn of the century, it is estimated that there were over 2,700 miles of underground mine tunnels and about 12,000 men employed in the mining industry. The population of Silver Bow County peaked around 1920, and has been on the decline ever since.*

The report summarizes the social and economic conditions in Silver Bow County with relative comparisons with the State of Montana. Part One deals with the general social and economic characteristics of Silver Bow County in relation to the State of Montana. Part Two analyzes the results of a socioeconomic survey of households neighboring abandoned mine sites in Silver Bow County. Part Three deals with values of real estate in Silver Bow County.

*Preliminary Report, Old West Regional Association, 1978.

PART I - General Social and Economic Characteristics of Silver Bow County in Relation to the State of Montana.

Exhibits 1-14 provide a host of information relating to the social and economic characteristics of Silver Bow County in relation to the State of Montana.

A. Land Area and Population

1. Silver Bow County is the smallest county in total land area, in the State of Montana. In 1980, the population of Silver Bow County was 38,092 with 53 people per square mile. Although the population per square mile might be considered small by some standards, it is large when compared with the sparcely populated State of Montana, with approximately 5.4 people per square mile. There is a higher percentage of older people, age 65 and older, living in Silver Bow County (15.0 percent in 1980 versus 12.2 percent in 1975) than in the overall State(10.8 percent in 1980 versus 10.0 percent in 1975.) (See exhibits 1 and 4.)
2. Population in the State of Montana increased by 13.3 percent from 1970 to 1980, from 694,409 to 786,690, while a rather sharp decline was experienced by Silver Bow County, -9.3 percent, from 41,981 to 38,092. While population in Montana increased by 2.9 percent from 1960 to 1970, it declined in Silver Bow County, by — 9.6 percent. (See exhibit 1.)
3. An even sharper decline in the population of Silver Bow County occurred over a larger period of time. From 1940 to 1980, the population in Silver Bow County declined by over 28 percent, from 53, 207 to 38,092, while the overall population of the State of Montana increased by over 40 percent, from 559,456 to 786,690. See exhibit 3.)

4. From 1970 to 1980, Silver Bow County experienced a net outmigration of -5,151 people, or -12 percent. There were 6,547 births and 5,285 deaths in the County. Population projections for the County show a decline in total population to 31,700 by the year 2000. In general, the county has a much smaller percent of its total population in the productive age group (ages 20 to 60) when compared with the State of Montana, and a much higher percent of its total population in the age 60 and above age group. (See exhibits 1 and 4.)

B. Health and Vital Statistics Characteristics

In 1980, Silver Bow County had 56 active physicians in the community, or a rate of 147 per 100,000 population as compared with a rate of 133 per 100,000 population for the State of Montana. There were two private hospitals with 320 beds and three private long-term health care facilities with 403 beds to service the community. Both the birth and death rates for the County were slightly lower than the birth and death rates for the State of Montana in 1980. (See exhibit 1.)

C. Educational Characteristics

School enrollment for Silver Bow County decreased considerably from 1975-76 to 1981-82, with a decline of over 2,000 FTE students in the public schools. The budgeted expenditures per pupil almost doubled over the same period, from $1,270 in 1975-76 to $2,333 in 1981-82. In 1980 69.1 percent of the County population were high school graduates, compared with 74.4 percent of the State population, and 14.2 percent of the County population had completed four or more years of college, compared with 17.5 percent of the State population. (See exhibits 1 and 10.)

D. Housing Characteristics

In 1980 there were 14,605 occupied housing units in Silver Bow County. This is a decline of over 1,000 units since 1960. The median value of occupied housing units was $31,600 in 1980 which is considerably less than the State average of $46,500 in 1980. Several relatively low income units are available for renters in the community. The median rent for renter occupied units was $149 per month in 1980. (See exhibit 1.)

E. Governmental Finances and Taxes

During the 1976-77 fiscal year, general revenues for governmental financing were in the amount of $30,429.000. The major share of government revenues came from state government, $8,302,000, and local taxes, $13,997. About two-thirds of government expenditures in 1976-77 were for educational and social services. In 1982 the property taxable value for Silver Bow County was in the amount of $47,571,000, with total taxes levied for all purposes in the amount of $21,755,380. The major portion of property tax valuation was derived from land and improvements, 47.3 percent, and personal property taxes, 31.0 percent in 1982. These rates were considerably higher than comparative rates for the State of Montana, 33.6 percent and 16.0 percent, respectively. (See exhibit 1.)

F. Public Assistance and Social Security Benefits

In 1982 public and medical assistance for residents of Silver Bow County was in the amount of $8,936,127, with the major portion in the form of medicaid payments. There were 8,242 Social Security recipients in Silver Bow County in 1980 with monthly cash benefits in the amount of $2,659,000. (See exhibit 1.)

G. Banking Services

In 1982 there were four banks in Silver Bow County with total assets in the amount of $196,769,000. (See exhibit 1.)

H. Income Characteristics

In 1979 the median family income in Silver Bow County was slightly higher than the median family income for the State of Montana, $19,572 versus $18,413, while the per capita income for Silver Bow County was similar to the per capita income for the State of Montana, $6,547 versus $6,589. The percent of persons below the poverty level was slightly lower in Silver Bow County in 1979 than in the State of Montana, 10.3 percent versus 12.3 percent. (See exhibit 1.)

I. Labor Force Characteristics

1. Labor Force Status 1970--1983 -

The civilian labor force increased in Silver Bow County from 15,516 in 1970 to 18,349 in 1981. Since 1981, the civilian labor force declined, considerably to 16,311 in September of 1983. This compares with a steady increase in the civilian labor force in the State of Montana, from 273,021 in 1970 to 392,000 in 1982. The number of females in the labor force in Silver Bow County increased from 5,539 in 1970 to 6,779 in 1980, for an increase of about 22 percent, compared with an increase of about 58 percent for the State of Montana. (See exhibits 1, 10, and 12.)

2. Employment and Unemployment -

The number of employed persons in Silver Bow County has declined from 16,900 in 1980 to 14,237 in 1983, a decline of about 16

percent. This compares with an increase in the State of Montana of about 4 percent over the same period. Since 1980, the unemployment rate has been considerably higher in Silver Bow County than in the State of Montana, ranging between 20 and 50 percent higher. (See exhibit 12.)

3. Employment by Industry, 1940--1980 -

   Total employment in Silver Bow County declined from 18,034 in 1940 to 14,871 in 1980. The major area of decline in total employment was experienced in the mining industry, which declined from 6,992 in 1940 to 1,746 in 1980. Employment in other industries in the County remained relatively stable over this period, with the service industry experiencing a considerable increase. In 1980, the service industry employed 4,828 people in Silver Bow County, of which 3,717 were in professional areas, including over 1500 in health care services and 1469 in educational services. (See exhibit 12.)

4. Employment by Occupations, 1980 -

   in 1980, 14,871 persons were employed in various occupations in Silver Bow County. Of the total, close to 8,000 were employed in various managerial, professional, technical, and sales occupations. (See exhibit 1.)

J. Population and Employment in Silver Bow County--Historical Trends -

1. The tremendous impact on employment by the mining industry in Silver Bow County is shown in Exhibit 13 which compares the numbers of workers in the mining industry with the numbers in all industries in Silver Bow County. It should be noted that the data listed in Exhibits 13 and 14 are incomplete because

these exhibits include only workers covered by unemployment insurance and are dated because this format was discontinued in 1973. The numbers of workers included comprise between 55 and 65 percent of the total, however, and important economic relationship can thus be observed. (See exhibit 13.)

2. From 1950 to 1952, the number of workers in the mining industry in Silver Bow County increased by about 1000, while the number of workers in all industry increased by about 2000. When a drop of about 3000 workers in the mining industry was experienced between 1952 and 1964, we find a decline of about 5000 workers in all industries covered. During the strike years, we can see an almost direct relationship between the loss of workers in the mining industry and the loss of workers in all industries covered. This indicates that employers and workers in the other industries most likely maintained their establishments on a marginal basis suffering out the strike. For example, employment in the mining undustry declined by about 2,700 workers from 1965 to 1968, while employment in all industries covered dropped by about 3,100 workers. Then, from 1969 to 1973, mining employment increased by about 1,000 employees while workers in all industries covered increased by about 3,000 workers. (See exhibit 13.)
3. Exhibit 14 provides the same comparisons for the State of Montana as Exhibit 13 provides for Silver Bow County. From Exhibit 14, we can see that the loss of employment in the mining industry does not have the harsh effects on total State employment as it does on employment in Silver Bow County. It is interesting to

note, however, the relationship between the declining numbers of workers in the mining industry and the increasing numbers of workers in all industries in the State of Montana. Between 1952 and 1973, workers in the mining industry dropped by about 40 percent, from 10,562 to 6,364. Over the same period, workers in all industries increased by about 48 percent, from 102,926 to 152,349. When Exhibit 14 is compared with Exhibit 13, we can see that the overall State employment has the capacity to absorb the loss of employment in the mining industry because the percent of total employment in this area is relatively small as compared to total employment. Just the opposite is true for Silver Bow County because of the extremely large percent of employment in the mining industry. (See exhibit 14.)

4. Exhibit 11 shows the relationship to employment in the mining industry in Silver Bow County with employment in other industries and County population. From 1940 to 1980, population in Silver Bow County declined by about 28 percent, from 53,207 to 38,092. At the same time, total employment for persons 16 years and older dropped by about 18 percent, from 18,034 to 14,871, while employment in the mining industry dropped by about 75 percent, from 6,992 in 1940 to 1,746 in 1980. It is interesting to note that for every job lost in the mining industry, the County lost about 3 people in population. Also, employment in other industries has not expanded sufficient enough to offset the loss of employment in the mining industry. Upon closer examination of the detailed categories listed in Exhibit 11, we find that the industry groups that did experience an increase in employment were mainly in the

non-basic industry areas. Employment in these service-related industries does not create the multiple employment effect in other industries as does employment in the basic industries such as mining and manufacturing. This is especially true for Silver Bow County which had such a large base of its total employment associated with the mining industry. (See exhibit 11.)

5. It is estimated that for every job in the basic industries in Silver Bow County, an additional 1.87 jobs are related to it, for a job multiplier of 2.87.* In 1970, about 22 percent of those employed in Silver Bow County were employed directly in the mining industry. With a multiplier of 2.87, this would mean that approximately 63 percent of the total employment in Silver Bow County was directly or indirectly related to the mining industry in 1970. (See exhibit 11.)
6. In 1977, employment in Silver Bow County averaged 15,618 workers. On December 31, 1977, the Anaconda Company employed 2,014 workers in Silver Bow County. Thus, in 1977, about 13 percent of the total employment in Silver Bow County was employed directly by the Anaconda Company. Most of these employees were found in the basic industry job classifications, which, as mentioned above, have a heavy influence as far as generating additional employment in other industries. If a 2.87 multiplier is applied to the employees of the Anaconda Company in 1977, about 38 percent of the jobs in Silver Bow County would have been directly

*Frank R. Lanow, Jr., The Economic Impact of Anaconda's Copper Operations in Montana, 1975.

or indirectly related to the employment of the Anaconda Company. An estimate provided shows that about 64 percent of the jobs in Deer Lodge and Silver Bow Counties were directly attributable to the Anaconda Company's activities in the area in 1973.*

K. Recent Employment Trends in Silver Bow County

1. From the above, we can observe the tremendous impact on population and employment in Silver Bow County, historically, by the mining industry in the community. From 1940 to 1970 there is a direct correlation between the decline in total population and employment in Silver Bow County with the decline in employment in the mining industry. Since 1970, however, some industry diversification in Silver Bow County has been experienced. (See exhibits 1 and 11.)
2. As indicated above, the Anaconda Company employed over 2,000 workers in 1977. In 1983, the Anaconda Company suspended operations in Butte-Silver Bow, and is presently maintaining a workforce of about 70 salaried employees. Although it's too early to determine what the long-run effect of the Company's suspension will have on the County's employment and population, and at some point in the future the Company may continue its operations if the price of copper increases to warrant its production in Silver Bow County, it is interesting to note that the historical harsh effects on employment and population by declining mining operations do not appear to be so severe in recent years. Offsetting factors to the loss of employment in the mining industry appear to be

---

*Frank R. Lanow, Jr.

taking place in Silver Bow County. As indicated above, employment in other industry groups, especially in the service industry, has expanded considerably in recent years. For example, the Montana College of Mineral Science and Technology has nearly tripled its enrollment, primarily with out-of-community students, over the last 10 years. The number of FTE employees at the College and the Bureau of Mines has increased from 226 in 1980-81 to 327 in 1983-84, and the total payroll has almost doubled, from $3,100,000 in 1980-81 to $7,600,000 in 1983-84. Other bright spots for employment stability in the County include an expansion of health service in the area and the prospect of a new gold mine that may soon begin operations southwest of Butte which would employ close to 100 workers over an 11-year period. Finally, it should be noted that many of the workers separated from the Anaconda Company with its operations suspension were phased out by early retirement. The retirement and pension benefits received by these people, plus benefits received by the relatively large number of persons over age 65 in the County help to provide income and population stability within the community.

PART II - Socioeconomic Survey

A. Survey Sample and Format

1. In November of 1983, a socioeconomic survey of households neighboring abandoned mine sites in Silver Bow County was conducted. Households neighboring abandoned mine sites north of Copper Street in Butte throughout Walkerville, east of Main Street and west of Excelsior Street in Butte and Walkerville were sampled. Surveys were forwarded to 125 households which comprize about 40 percent of all households neighboring abandoned mine sites in this area. Prior to the survey mailing, Mayor Donald Peoples of Butte-Silver Bow forwarded a letter to these households, encouraging the occupants to respond to the survey in order to elicit a good return. Of the 125 surveys forwarded, 7 were not delivered and 68 were completed and returned. Thus, about 58 percent of the surveys received by the households sampled were completed and returned, or surveys were completed and received by about 22 percent of the total number of households neighboring abandoned mine sites in this area, making this a representative sample of the persons in the area.
2. The survey was divided into two main categories. Part I listed questions which attempted to identify the feelings of residents concerning abandoned mine sites near their homes. The questions covered nine categories which dealt with the respondents' feelings and attitudes ranging from their general positive or negative feelings towards abandoned mine sites in their neighborhoods to their attitudes regarding reclamation of these abandoned mine sites. Part II of the survey asked the respondents to help

identify safety and health hazzards associated with abandoned mine sites in their area. It should be noted that most of the respondents to the survey had been homeowners in the area for many years. (See exhibits 15, 16, and 17.)

B. Survey Results and Interpretation

1. A simple analysis of the answered questions was completed by determining the number and percent of positive and negative answers to each question. The number and percentage for each answered question may not equal 68 because not all respondents answered all the questions. From this analysis, conclusions were drawn as to the consensus of the respondents.
2. The analysis of the data received from question 1 which dealt with the general feelings of the respondents towards abandoned mine sites, 34% of the 59 respondents reported that they had positive feelings towards abandoned mine sites and 66% of the respondents indicated a negative attitude toward abandoned mine sites in their neighborhood.
3. Of the 60 respondents answering question 2, dealing with abandoned mine sites as a positive image of the past and strength for the future, 28%, or 17 respondents, indicated that they felt abandoned mine sites produced positive images of the past and strength for the future, while 72% or 43 respondents, felt they did not perceive abandoned mine sites as positive for the past or future.
4. 18 of the 60, or 30%,stated that abandoned mine sites would help us to look with strength to the future. However, 42 of the respondents answered the question negatively. Thus, 70% of the answers were negative. It must be noted here that questions 2 and 3 were

extremely similar in their attempt to measure attitudes about the images that abandoned mine sites created in the respondents. The results of the analysis showed that only one respondent changed answers from question 1 to question 3, indicating that the respondents understood the questions and reported their feelings to each question similarly.

5. Thirty-four or 55% of the answers to question 4, which asked about the feelings of signs of failure, indicated that abandoned mine sites did represent community failure while 28 of the 62 respondents, representing 45%, reported that abandoned mine sites did not represent community failure.
6. In answering question 5, which consisted of the positive and negative image abandoned mine sites represent to children, 16 respondents said that abandoned mine sites represented positive images for children. This represented 31% of the 52 people answering the question. On the other hand, 69% or 36 respondents, felt that abandoned mine sites provided negative images for children.
7. Question 6 dealt with property values close to abandoned mine sites. Fifty-six of the answers indicated that the respondents felt property values were reduced because of abandoned mine sites. Thus, of the 59 respondents to this question, 95% indicated they felt that property values were reduced while only 5%, or 3 respondents, believed that abandoned mine sites enhanced property values.
8. "Do you feel that the Mining Museum is enough of a link with the past?", was question 7. Thirty-four people, representing 56% of the respondents, felt that the Mining Museum was enough of a link with the past whereas 27 respondents, or 44%, felt that the

Mining Museum was not enough of a link with the past.

9. When asked if abandoned mine sites close to their homes should be preserved, 17, or 28% said that the sites should be preserved, but 44, or 72% indicated that the mine sites close to their home should not be preserved.
10. Question 9, which 59 people responded to, asked about the possibility of reclaiming abandoned mine sites near their residences with no direct cost to the occupant. Eight of the responses were negative; that is, 13% felt that they were not for reclamation. In answering the same question, 51, or 86%, advised that they were in favor of reclamation.
11. Under Part II of the survey, dealing with identification of safety and health hazzards associated with abandoned mine sites in their area, 26 respondents commented on sources of dust from abandoned mine sites, 20 identified areas where the ground has settled or holes had opened, 18 commented on flooding from inactive mine sites in their neighborhoods, and 28 respondents identified open shafts or other potentially dangerous conditions associated with inactive mines in their neighborhoods. Finally, 24 respondents listed other concerns regarding abandoned mine sites in their area. (See exhibit 17.)

C. Conclusion

It is evident that the consensus of the respondents strongly indicates that they are in favor of abandoned mine reclamation. From the survey results, it is apparent that the physical environment associated with abandoned mine sites has an adverse effect not only with the community

image, but even more significantly, on the self-concept of each individual in the community. Because abandoned mine sites represent negative images to the majority of people living close to them, it is felt that any efforts towards reclamation would provide a positive impact to the community.

Part III - Property Valuations and Housing Characteristics in Butte-Silver Bow

A. Housing Characteristics

Exhibit 18 provides information relating to housing characteristics in Silver Bow County. While the number of housing units in Montana increased from 220,544 in 1960 to 315,015 in 1980, an increase of 43 percent, the number of units in Butte-Silver Bow declined from 17,790 to 16,031, a decline of 10 percent. The median value of owner-occupied housing units in Butte-Silver Bow was $31,600 in 1980, or only about 68 percent of the median value of owner-occupied housing units for the State of Montana which was $46,500 in 1980. Contracted rental payments for renter-occupied units were considerably lower in Butte-Silver Bow, $110.00 per month in 1980, than in the State of Montana, $165.00 per month in 1980. (See exhibit 18.)

B. Homeowners Attitudes Towards Property Valuations

From the socioeconimic survey as described under Part II, above, it was learned that homeowners neighboring abandoned mine sites in Butte - Silver Bow feel these abandoned mine sites reduce their property values. As indicated above, 66 percent of the respondents indicated negative feelings towards abandoned mine sites in their neighborhoods, and 95 percent of the respondents felt that the abandoned mine sites in their neighborhoods reduced their property values. In this regard, 86 percent of the respondents advised that they would be in favor of reclamation of abandoned mine sites in their neighborhoods. This implies that these people would expect reclamation to enhance their property values. (See exhibit 17.)

C. Property Valuations Near Abandoned Mine Sites

From an interview with a real-estate appraiser with considerable experience with property valuations in Butte-Silver Bow, it was learned that housing units located near abandoned mine sites in the North Butte or "Hill" Area, are in general, low-value properties. Reclamation of abandoned mine sites in these areas would most likely be associated with only limited enhancement of property valuations because of the relatively low base valuations of the structures and land in the areas. Reclamation of abandoned mine sites in other areas of the community would most likely be associated with a more profound enhancement of property values, however.*

As indicated above, values of housing units in Butte-Silver Bow are considerably lower than similar values for the State of Montana. A relatively large percent of housing units are located near abandoned mine sites in Butte-Silver Bow. This tends to bring the median and average values of all housing units in the community down. Finally, to show that abandoned mine sites do have an adverse effect on property valuations, it was learned that, if houses presently located near abandoned mine sites in the North Butte area were located in other areas of the community, for example in the Hillcrest area, the values of these houses would be enhanced from 10 to 60 percent.*

*Interview with Murray C. Lind, Real Estate Appraiser, January 3, 1984.

Socioeconomic Study - Exhibit 1

Summary of Social and Economic Characteristics

Montana and Silver Bow County, 1980

Description	Montana	Silver Bow County
1. Land Area	145,392	719
2. Persons Per Square Mile	5.4	53.0
3. Population		
a. 1960	674,767	46,454
b. 1970	694,409	41,981
c. 1980	786,690	38,092
d. Percent Change 1960-70	2.9	-9.6
e. Percent Change 1970-80	13.3	-9.3
4. Households		
a. Total	283,742	14,605
b. Married Couple	178,606	8,287
c. One Person	66,350	4,351
5. Components of Population Change 1970-80		
a. Births		6,547
b. Deaths		5,285
c. Net Migration		-5,151
(Percent)		-12
6. Population Projection		
a. 1990	860,000	35,300
b. 2000	936,000	31,700
7. Criminal Offenses and Crime Rates		
a. Criminal Offenses	36,791	1,469
b. Crime Rates/1000 persons	46.8	38.6

Summary, Page 2

Description	Montana	Silver Bow County
8. Health and Hospitals 1980 (*Indicates Rate Per 100,000 Population)		
a. Physicians (Active, Non Federal)	1,050 (133.5)*	56 (147.0)*
b. Dentists (Active, Non Federal)	465 (59.1)*	28 (73.5)*
c. Nurses, Licensed (RN & LPN)	8,869 (1.127)*	616 (1.617)*
d. Private Hospitals	61	2
Beds	3,405 (432.)*	320 (840)*
e. Private Long-Term Care Facilities	93	3
Beds	5,891 (749)*	403 (1058)*
9. Selected Vital Statistics 1980		
a. Number of Live Births	14,208	585
b. Out-of-Wedlock Births/1000	125.0	126.0
c. Number of Deaths	6,664	520
d. Infant Deaths	176	9
e. Marriages Solemnized	8,336	376
f. Marrital Terminations	4,940	154
g. Births/1000 population	18.1	15.4
h. Deaths/1000 population	8.5	13.7
10. Educational Characteristics		
a. FTE Public School Enrollment 1975-76		8,816
b. FTE Public School Enrollment 1981-82		6,668
c. Pupil-Teacher Ratio 1975-76		18.7
d. Pupil-Teacher Ratio 1981-82		16.7
e. Budgeted Expenditure Per Pupil 1975-76		$1,270
f. Budgeted Expenditure Per Pupil 1981-82		$2,333

Summary, Page 3

Description	Montana	Silver Bow County
11. Housing Characteristics		
a. Occupied Housing Units, 1980	283,742	14,605
b. Occupied Housing Units 1960	202,240	15,334
c. Median Value, Occupied Housing Units, 1980	$46,500	$31,600
d. Median Rents for Renter Occupied Units, 1980		$149
12. Labor Force Status (16 and over)		
a. Labor Force, 1980	362,656	16,364
b. Employed, 1980	328,316	14,871
c. Unemploment Rate, 1980	8.3	8.9
d. Females Employed, 1980	145,076	6,779
e. Females Employed, 1970	91,669	5,539
f. Occupational Category, 1980		
1.) Total		14,871
2.) Technical, Sales & Adm. Support		4,412
3.) Managerial and Professional		3,449
4.) Service		2,750
5.) Farming, Forestry & Fishing		116
6.) Precision Production, Craft		2,084
7.) Operators, Fabricators & Laborers		2,060
g. Industry Category, 1980		
1.) Total		14,871
2.) Agriculture, Forestry, Fishing & Mining		1,959
3.) Construction		714
4.) Manufacturing		702
5.) Transportation, Communication & Utilities		1,939
6.) Wholesale-Retail Trade		3,233
7.) All Other		6,324

Summary, Page 4

Description	Montana	Silver Bow County
h. Females With Children Under 18		
1.) Percent in Labor-Force, 1980	54.4	54.5
2.) Percent in Labor-Force, 1970	39.9	38.1
13. Income Characteristics		
a. Median Family Income, 1979	$18,413	$19,572
b. Median Family Income, 1969	$ 8,512	$ 8,671
c. Families Below Poverty Level, 1979	19,019	774
d. Households With Public Assistance, 1979	14,256	936
e. Per Capita Personal Income, 1981		$ 9,908
f. Per Capita Personal Income %of National 1981	89.7	94.4
14. Governmental Finances, 1976-77 ($000's)		
a.) General Revenues		$30,429
1.) From Federal Government		$ 2,760
2.) From State Government		$ 8,302
3.) From Local Taxes		$13,997
4.) Charges and Miscellaneous		$ 5,370
b.) Direct General Expenditures		$30,378
1.) Educational Services		$15,723
2.) Social Services		$ 4,266
3.) All Others		$10,389

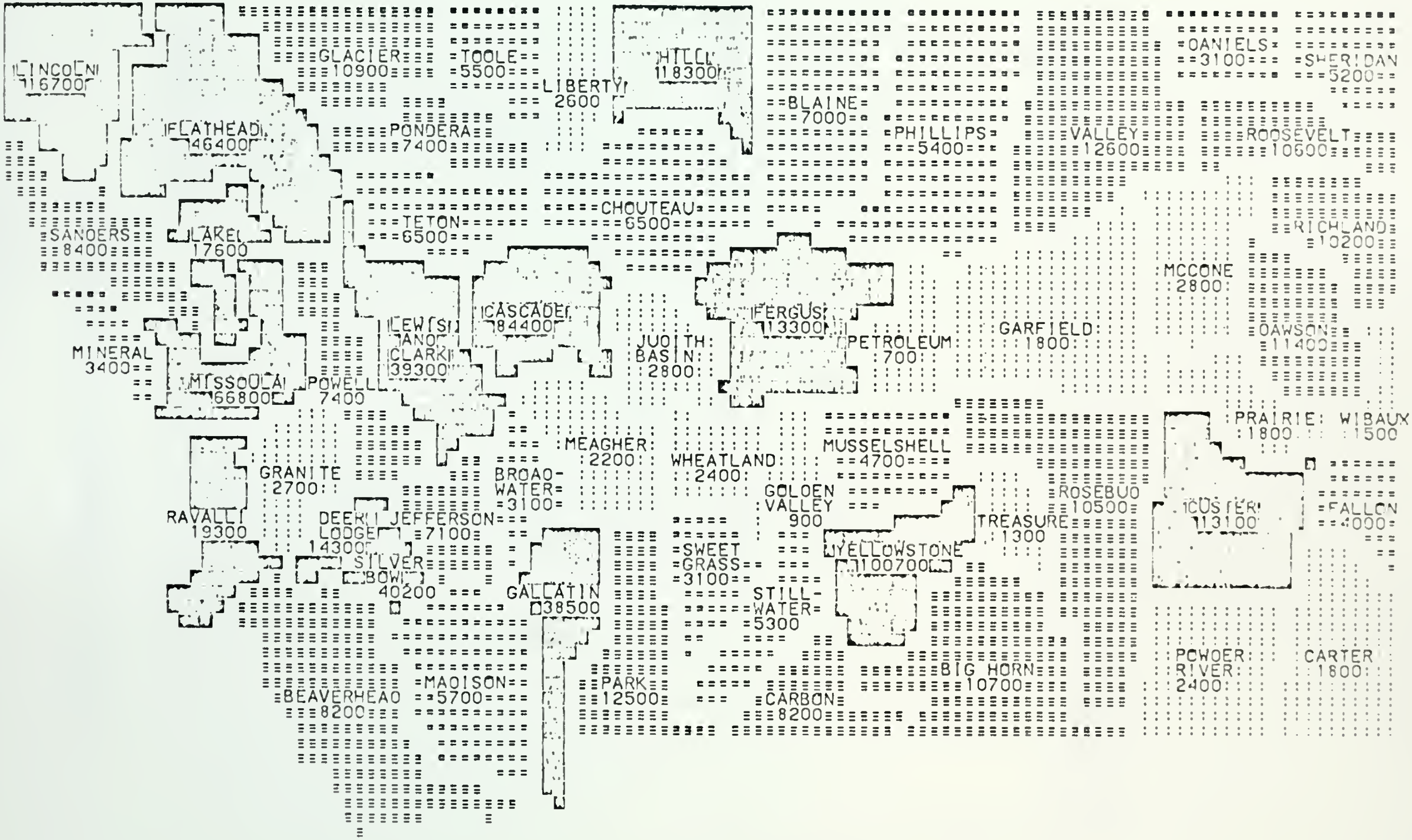
Summary, Page 5

Description	Montana	Silver Bow County
15. Property Tax Base, 1982 ($000's)		
a. Taxable Value	$2,204,492	$47,571
1.) Land and Improvements (Percent)	33.6	47.3
2.) Personal Property	16.0	31.0
3.) Livestock	1.4	0.1
4.) Net and Gross Proceeds, Royalties	34.1	5.2
5.) Utilities	14.9	16.4
b. Total Taxes Levied for All Purposes, 1982		$21,755,380
16. Social Security Benefits, 1980		
a. Total Beneficiaries	119,496	8,242
b. Monthly Cash Benefits ($000's)	$35,483	$2,659
17. Public Assistance and Medical Assistance, 1982		
a. Public Assistance, All Programs	$125,831,126	$8,936,127
b. AFDC	$ 18,455,938	$1,220,335
c. Medicaid	$74,837,496	$5,866,007
d. Food Stamps	$ 23,322,187	$1,269,431
18. Banking and Monetary Data, 1982		
a. Total Assets All Banks ($000's)		$196,769
b. Total Liabilities All Banks ($000's)		$182,345
c. Number of Banks	165	4

Source: U.S. Department of Commerce, Bureau of the Census, Montana County Profiles, Silver Bow County, Fourth Edition, 1983. (Published by The Census and Economic Information Center, Consulting Services Bureau, Department of Administration, Helena, Montana.)

Exhibit 2

MAP 1.1.0 ESTIMATED POPULATION: 1977



SOURCE: U.S. BUR OF THE CENSUS
CURRENT POPULATION REPORTS
SERIES P-26

:::: 700 - 2800 LOW QUARTILE
▪▪▪▪ 3100 - 7000 MEDIUM LOW QUARTILE
≡≡≡≡ 7100 - 12600 MEDIUM HIGH QUARTILE
▨ 13100 - 100700 HIGH QUARTILE

MEAN VALUE: 13593
MEDIAN VALUE: 7050
STATE VALUE: 761000

Socioeconomic Study - Exhibit 3

Population of Montana and Silver Bow County
1940-1980

Year	Silver Bow County	State of Montana
1940	53.207	559,456
1950	48,422	591,024
1960	46,454	674,767
1970	41,981	694,409
1971	42,900	709,400
1972	42,100	716,100
1973	43,300	729,800
1974	43,100	737,000
1975	43,000	746,000
1976	41,000	753,000
1980	38,092	786,690

Percent Changes

Period	Silver Bow County	State of Montana
1940-1980	- 28.4%	40.6%
1950-1980	- 21.3%	33.1%
1960-1980	- 18.0%	16.6%
1970-1980	- 9.3%	13.3%

Sources: United States Department of Commerce, Bureau of the Census, Census of the Population, 1940, 1950, 1960, 1970, and 1980, and Series P-25 and P-26, Population Estimates.

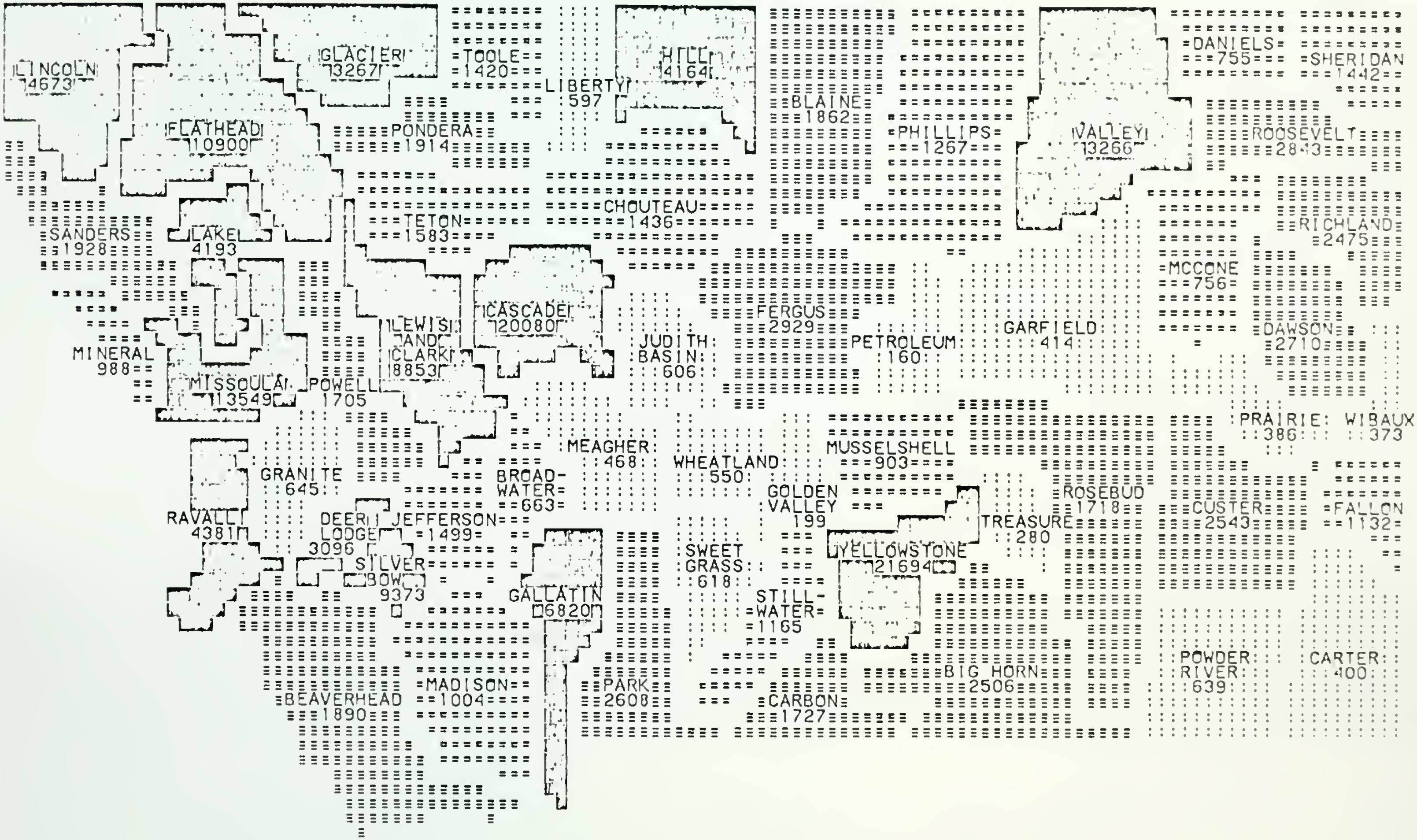
Population of Montana and Butte-Silver Bow, By Age, 1980

	Montana		Silver Bow County	
Age Group	Number	Percent Distribution	Number	Percent Distribution
Total	786,690	100.0	38,092	100.0
Under 5	64,445	8.2	2,641	6.9
5-9	60,238	7.7	2,787	7.3
10-14	62,539	7.9	3,195	8.4
15-19	74,622	9.5	3,558	9.3
20-24	74,018	9.4	2,960	7.8
25-29	71,516	9.1	2,849	7.5
30-34	61,409	7.8	2,583	6.8
35-39	48,095	6.1	2,177	5.7
40-44	40,374	5.1	1,853	4.9
45-49	36,314	4.6	1,725	4.5
50-54	37,363	4.7	1,927	5.1
55-59	36,557	4.6	1,915	5.0
60-64	34,681	4.4	2,236	5.9
65-69	29,609	3.8	2,006	5.3
70-74	21,919	2.8	1,542	4.0
75-79	14,922	1.9	1,060	2.8
80-84	9,272	1.2	596	1.6
85 and over	8,837	1.1	482	1.3
Median Age	29.0		32.0	

Source: U.S. Department of Commerce, Bureau of the Census, Census of the Population, Montana, 1980.

Exhibit 5

MAP 3.7.0 SIX-YEAR AVERAGE PUBLIC SCHOOL ENROLLMENT: 1971 TO 1976



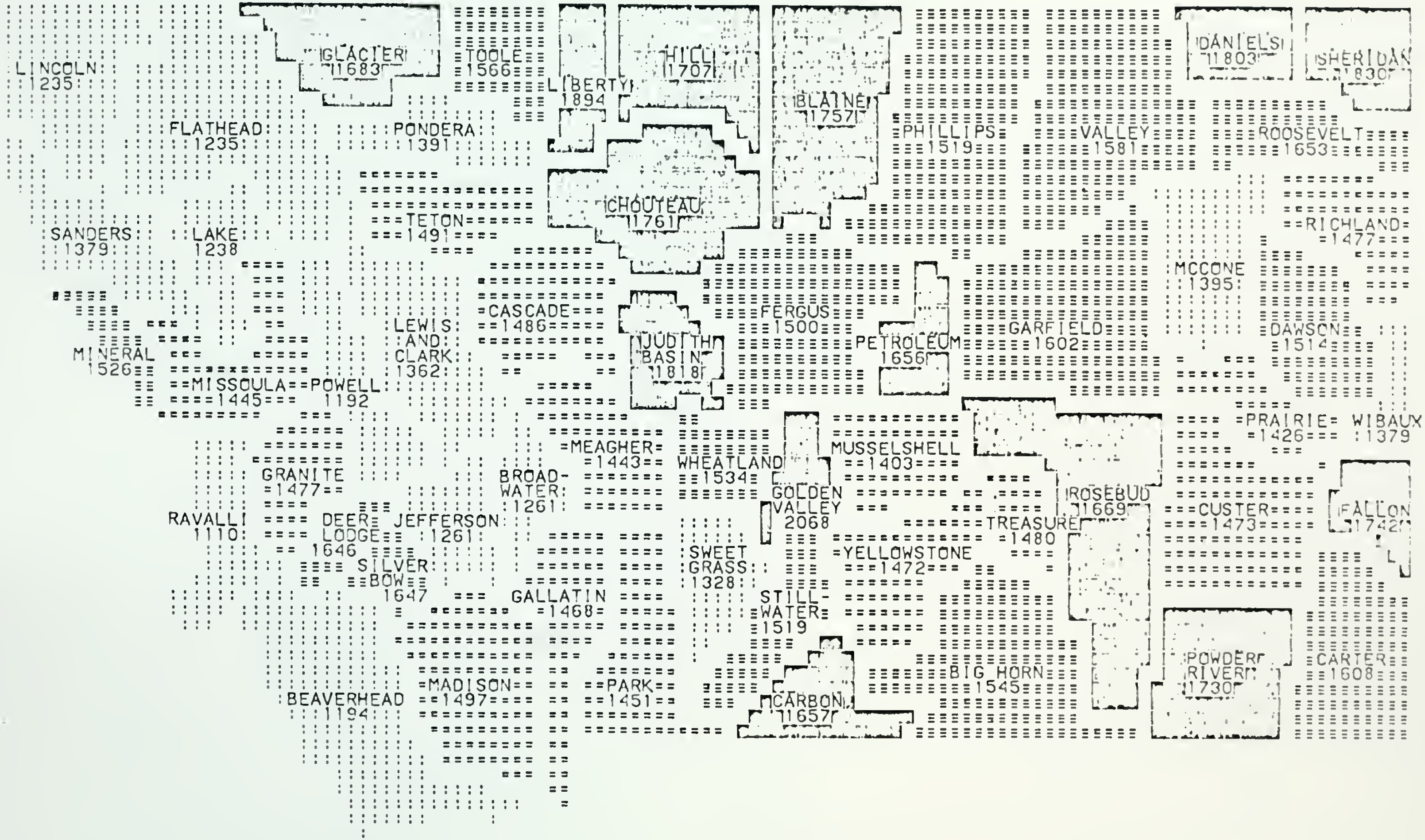
SOURCE: MONTANA COUNTY PROFILES
(OFFICE OF SUPT. OF
PUBLIC INSTRUCTION)

:::: 160 - 645 LOW QUARTILE
==== 663 - 1583 MEDIUM LOW QUARTILE
≡≡≡≡ 1705 - 2929 MEDIUM HIGH QUARTILE
▨ 3096 - 21694 HIGH QUARTILE

MEAN VALUE: 3072
MEDIAN VALUE: 1644
STATE VALUE: 172011

Socioeconomic Study
Exhibit 6

MAP 3.9.0 BUDGETED SCHOOL EXPENDITURE PER PUPIL (ALL DISTRICTS): 1977-78



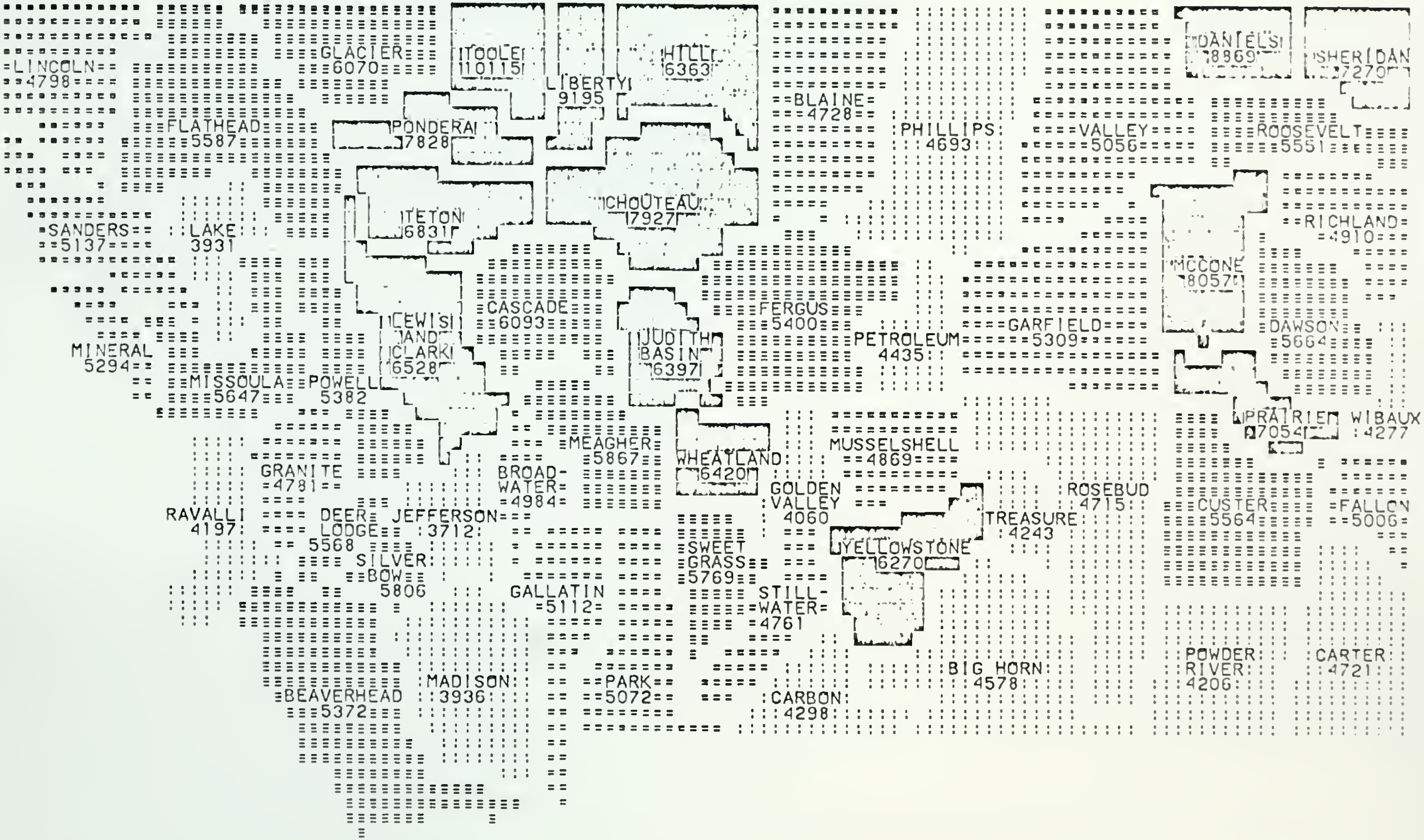
SOURCE: MONTANA COUNTY PROFILES
(OFFICE OF SUPT. OF
PUBLIC INSTRUCTION)

:::: 1110 - 1395 LOW QUARTILE
==== 1403 - 1497 MEDIUM LOW QUARTILE
▨ 1500 - 1653 MEDIUM HIGH QUARTILE
☐ 1656 - 2068 HIGH QUARTILE

MEAN VALUE: 1521
MEDIAN VALUE: 1499
STATE VALUE: 1466

Exhibit 7

MAP 6.5.0 PER CAPITA INCOME: 1976



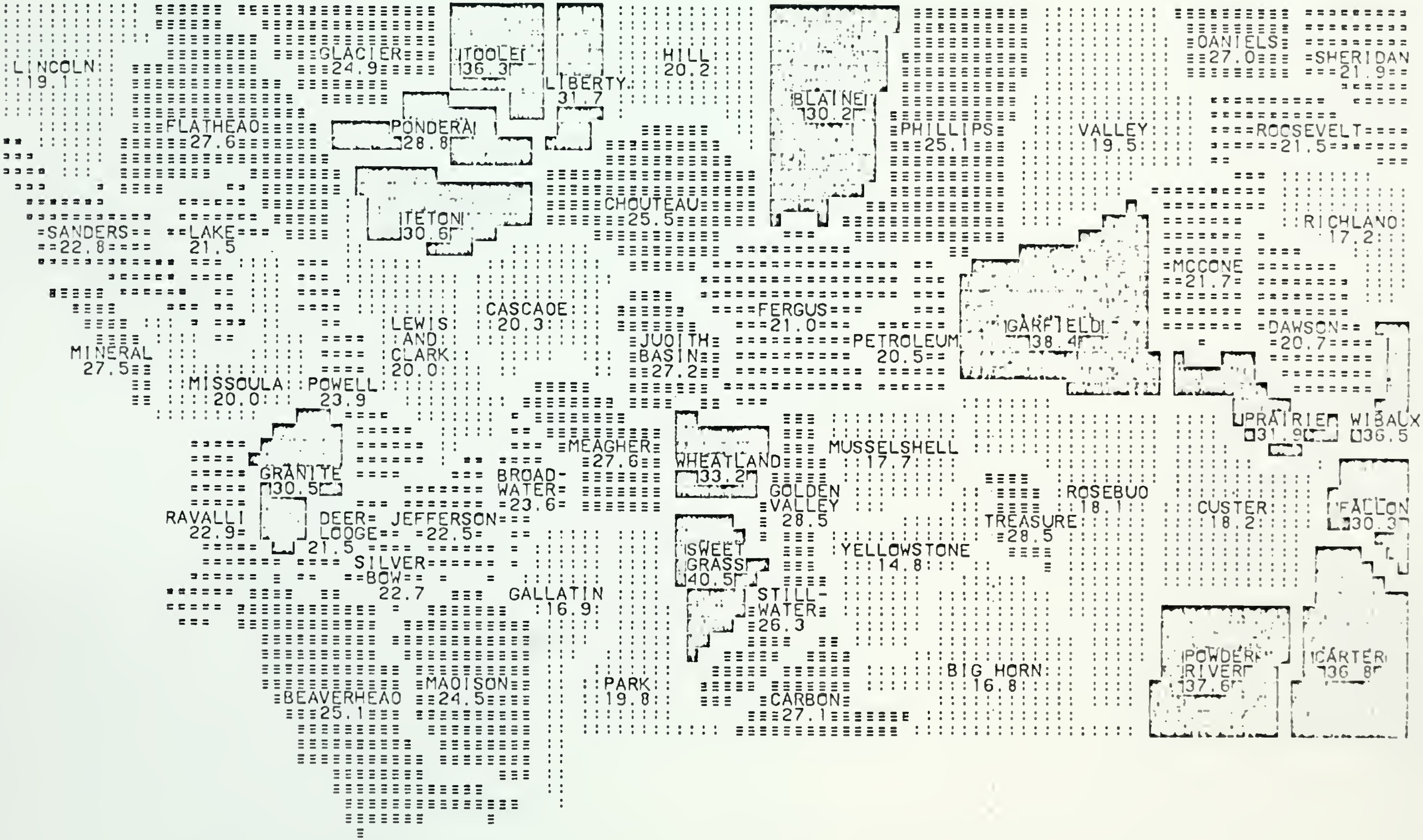
SOURCE: BUR. OF ECONOMIC ANALYSIS,
U.S. DEPT. OF COMMERCE
(REIS MAGNETIC TAPE)

::::	3712 - 4721	LOW QUARTILE
====	4728 - 5309	MEDIUM LOW QUARTILE
≡≡≡≡	5372 - 6093	MEDIUM HIGH QUARTILE
▭	6270 - 10115	HIGH QUARTILE

MEAN VALUE: 5612
MEDIAN VALUE: 5341
STATE VALUE: 5691

Exhibit 8

MAP 7.5.0 PROPERTY TAXES LEVIED FOR COUNTY PURPOSES; PERCENT OF ALL PROPERTY TAXES: 1977

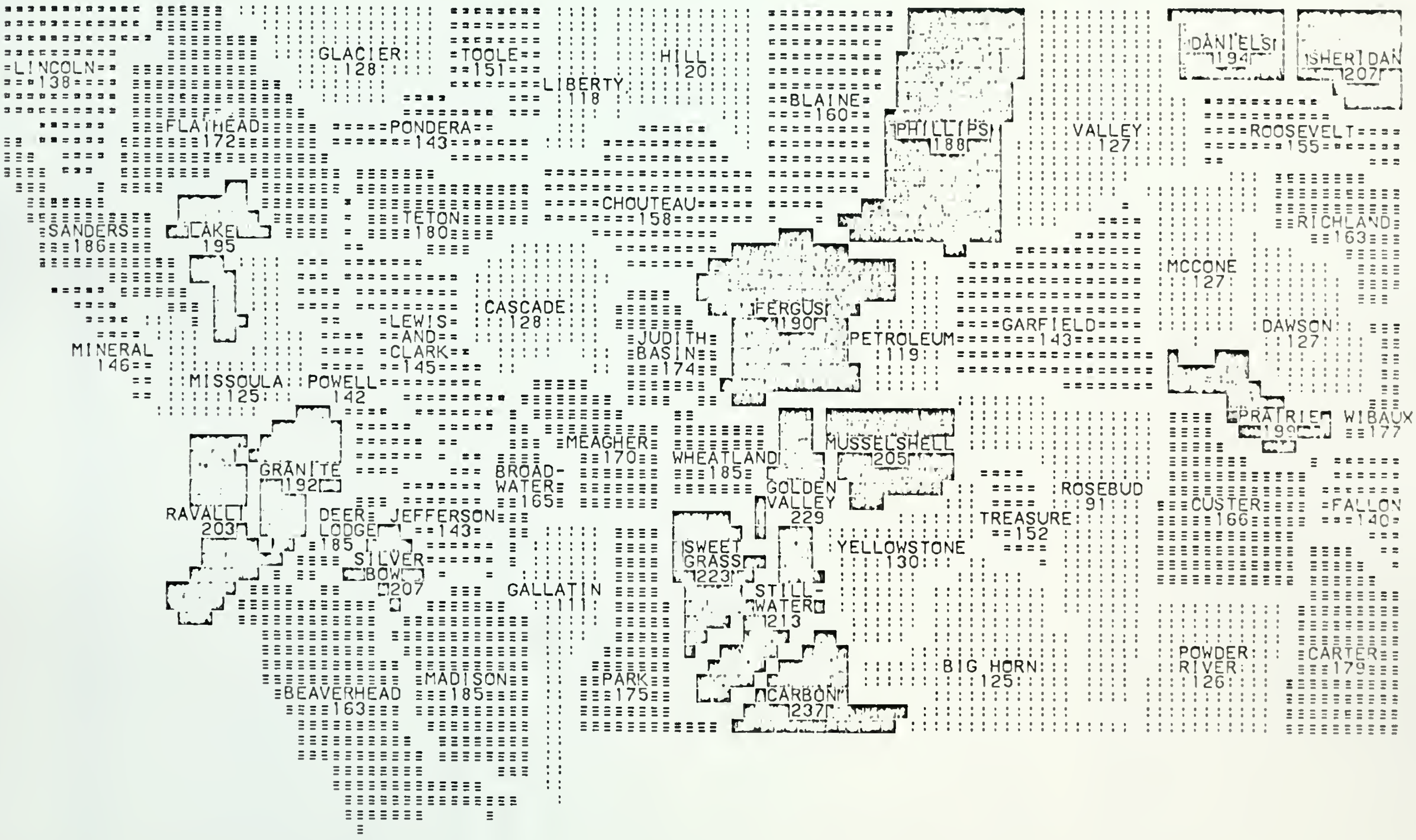


SOURCE: MONTANA COUNTY PROFILES
(STATE DEPT. OF REVENUE)

::::	14.8 - 20.3	LOW QUARTILE
====	20.5 - 23.9	MEDIUM LOW QUARTILE
≡≡≡≡	24.5 - 28.5	MEDIUM HIGH QUARTILE
▨	28.8 - 40.5	HIGH QUARTILE

MEAN VALUE: 25.2
MEDIAN VALUE: 24.2
STATE VALUE: 25.3

MAP 8.1.0 SOCIAL SECURITY BENEFICIARIES: END OF DEC. 1977
(PER 1,000 POPULATION)



SOURCE: MONTANA COUNTY PROFILES
(SSA, HEW; AND
U.S. BUR OF THE CENSUS)

:::: 91 - 130 LOW QUARTILE
==== 138 - 160 MEDIUM LOW QUARTILE
≡≡≡≡ 163 - 186 MEDIUM HIGH QUARTILE
▨ 188 - 237 HIGH QUARTILE

MEAN VALUE: 163
MEDIAN VALUE: 163
STATE VALUE: 151

Summary of Economic Characteristics, Montana and Butte-Silver Bow

1980

	Montana	Butte-Silver Bow
Percent in Labor Force:		
Male, 16 years and over	75.2	69.7
Female, 16 years and over		
Total	49.0	45.5
With Children Under 6 Years	44.6	41.0
Non workers per 100 workers	117	133
Civilian Labor Force-Percent Unemployed	8.3	8.9
Percent of Families with no Workers	10.3	15.6
Median Income in 1979 dollars		
Households	$15,420	$14,591
Families	$18,413	$19,572
Per Capita Income in 1979 dollars	$ 6,589	$ 6,547
Income in 1979 below poverty level		
Percent of Persons	12.3	10.3
Percent of Families	9.2	7.7
Persons 25 years and older		
Percent of high-school graduates	74.4	69.1
Percent completed 4 or more years of college	17.5	14.2
Percent of Families with Own Children under 6 years	25.3	22.0

Source: United States Department of Commerce, Bureau of the Census, Census of the Population, Montana, 1980.

Socioeconomic Study - Exhibit 11

County Population and Employment by Industry
Silver Bow County, 1940-1980

	1940	1950	1960	1970	1980
Total County Population	53,207	48,422	46,454	41,981	38,092
Number of Employed Persons by Industry					
Total	18,034	18,632	15,399	14,543	14,871
Agriculture	254	252	175	250	213
Mining	6,992	6,006	3,294	2,970	1,746
Construction	485	781	736	691	714
Manufacturing	937	1,195	1,286	921	702
Wholesale-Retail Trade	3,510	4,324	3,627	3,369	3,233
Finance, Insurance, and Real Estate	431	539	564	613	548
All Other Industry Groups	5,425	5,535	5,717	5,729	7,715

Sources: United States Department of Commerce, Bureau of the Census, Census of the Population, Montana, 1940, 1950, 1960, 1970, and 1980.

Socioeconomic Study - Exhibit 12

Employment in Montana, Anaconda-Deer Lodge, and Butte-Silver Bow, 1970-1983

	1970*	1975*	1980**	1981**	1982**	9/83**
Montana-Statewide						
Civilian Labor Force	273,021	322,575	370,000	384,000	392,000	385,393
Employment	261,171	301,961	347,000	357,000	358,000	360,013
Unemployment	11,850	20,614	23,000	27,000	34,000	25,380
Percent Unemployed	4.3	6.4	6.1	6.9	8.6	6.6
Anaconda-Deer Lodge						
Civilian Labor Force	5,877	6,609	5,048	4,911	4,587	4,469
Employment	5,734	6,181	4,568	4,070	3,903	3,811
Unemployment	143	428	480	841	684	658
Percent Unemployed	2.4	6.5	9.5	17.1	14.9	14.7
Butte-Silver Bow						
Civilian Labor Force	15,516	17,641	18,140	18,349	17,895	16,311
Employment	14,904	16,207	16,900	16,824	15,878	14,237
Unemployment	612	1,434	1,240	1,525	2,017	2,074
Percent Unemployed	3.9	8.1	6.8	8.3	11.3	12.7

*1979 Benchmark

**1982 Benchmark

Source: Montana Department of Labor and Industry, Research and Analysis Bureau, Montana Employment and Labor Force, 1980-1982, and Statistics In Brief, October, 1983.

Employers, Workers, and Wages in All Major Industries and in The Mining Industry in Silver Bow County, 1950-1973

	All Industries			Mining Industry					
				Employers		Workers		Wages(in 000's)	
Year	Employers	Workers	Wages(in 000's)	Number	% of All	Number	% of All	Amount	% of All
1950	1,101	12,768	$37,130	20	1.8%	5,626	44%	$18,471	49.7%
1952	1,141	14,351	54,105	17	1.5	6,609	46	29,712	54.9
1964	936	9,697	53,826	10	1.1	3,702	38	23,809	44.2
1965	946	9,957	56,008	10	1.1	4,140	42	26,954	48.1
1968	903	6,824	40,759	10	1.1	1,434	21	11,983	29.4
1969	879	7,882	51,668	8	.9	2,581	33	21,739	42.1
1970	874	9,102	62,675	9	1.3	3,008	33	27,633	44.1
1973	918	10,867	86,782	8	.9	3,532	32	37,497	43.2

Sources: Montana Employment Security Division, Department of Labor and Industry, "Industrial Wages, Wage Earners, Employers by Counties and Industries," Helena, Montana, 1951-1974.

Socioeconomic Study - Exhibit 14

Employers, Workers, and Wages in All Major Industries and in The Mining Industry in State of Montana, 1950-1973

	All Industries			Mining Industry					
				Employers		Workers		Wages(in 000's)	
Year	Employers	Workers	Wages(in 000's)	Number	% of All	Number	% of All	Amount	% of All
1950	14,100	98,769	$ 271,825	463	3.2%	9,483	9.6%	$31,502	11.6%
1952	14,173	102,926	338,291	474	3.3	10,562	10.3	46,941	13.8
1964	16,044	112,883	537,249	433	2.7	7,163	6.3	45,224	8.4
1965	16,143	115,124	564,474	421	2.6	7,456	6.5	49,047	8.7
1968	16,234	118,976	645,745	416	2.6	4,673	3.9	35,032	5.4
1969	16,192	123,753	704,060	440	2.7	6,146	5.0	48,736	6.9
1970	16,404	125,376	745,705	437	2.7	6,600	5.3	55,927	7.5
1973	18,059	152,349	1,045,428	372	2.1	6,364	4.2	65,778	6.3

Sources: Montana Employment Security Division, Department of Labor and Industry, "Industrial Wages, Wage Earners, Employers, by Counties and Industries," Helena, Montana, 1951-1974.

Socioeconomic Study - Exhibit 15

BUTTE-SILVER BOW
COURTHOUSE
BUTTE, MONTANA 59701

OFFICE OF
CHIEF EXECUTIVE

AREA CODE 406
PHONE 723-8262

November 4, 1983

Memorandum to: Persons Living Near Abandoned Mine Sites in Silver Bow County

From: Donald Peoples, Mayor, Butte-Silver Bow

Re: Comprehensive Study of Abandoned Mine Sites in Silver Bow County

Hydrometrics of Helena, Montana, has been contracted to develop a Comprehensive Reclamation and Engineering Study dealing with Abandoned Hard Rock Mines in Silver Bow County. The study is being funded by the Abandoned Mines Reclamation Bureau of the Department of State Lands, and will deal with health, safety or environmental hazards associated with abandoned hard rock mines in Silver Bow County. If conditions exist which meet Department of State Lands' specification, funding for reclamation of these lands may be provided.

Joe Kasperick and Tom Lester of Butte have been contracted to investigate the socioeconomic aspects of the comprehensive plan. As a part of their study, they will be conducting a socioeconomic survey of persons living near abandoned mine sites in Silver Bow County. In a few days, you will receive a questionnaire they have developed regarding your attitudes toward abandoned mine sites in your neighborhood and seeking information regarding any safety, health or environmental problems associated with them. In order to provide them with a workable sample, I urge you to complete the questionnaire as soon as possible and return it to them.

Your assistance and cooperation is appreciated.

Socioeconomic Study - Exhibit 16

ECONSULT, INC.
1146 WEST STEEL, BUTTE, MONTANA 59701
(406) 782-1626
HOME (406) 723-9532
Joseph E. Kasperick
President

November 9, 1983

Memorandum to: Persons Living Near Abandoned Mine Sites in Silver Bow County

From: Joseph E. Kasperick jek and Thomas Lester TL

Re: Socioeconomic Survey

We are associated with Hydrometrics of Helena, Montana, to investigate the socioeconomic aspects of a comprehensive study dealing with abandoned hard rock mines in Silver Bow County. The study is funded by the Abandoned Mine Reclamation Bureau of the Department of State Lands.

Briefly, the comprehensive study will document and determine conditions at abandoned mine sites in Silver Bow County that are creating health, safety or environmental hazards and will develop various alternatives to correct these problems. If conditions exist with abandoned mined lands which meet Department of State Lands' specifications, funding for reclamation of these lands may be provided.

We feel that people living near abandoned mine sites should have an opportunity to express their concerns. Thus, as a part of the socioeconomic study, we have developed the enclosed survey as a means for you to let us know how you feel about abandoned mine sites in your neighborhood, and of any health or safety problems associated with them.

In order to help us with our study, we ask that you please take a few minutes of your time and complete the enclosed survey. A self-addressed, stamped envelope is enclosed for you to return the completed survey.

Thank you for your assistance and cooperation.

ARTCRAFT, BUTTE

Socioeconomic Study - Exhibit 17

Socioeconomic Survey of Households Located Near
Abandoned Mines Located in Butte - Silver Bow

Below, please find questions pertaining to the socioeconimic aspects of a comprehensive study being conducted on abandoned mine sites in Silver Bow County. We ask that you please take a few minutes to answer these questions and return this form in the enclosed, self-addressed, stamped envelope.

Thank you for your assistance and cooperation.

I. Please answer the following questions according to the way you feel.

1. Do you have a positive or a negative feeling towards abandoned mine sites in your neighborhood? Positive 20 Negative 39
2. Do you perceive the abandoned mine sites as a positive image of the past in providing strength for the future? Yes 17 No 43
3. Do you see abandoned mine sites as signs which will help us look with strength to the future? Yes 18 No 42
4. Do you see abandoned mine sites as signs which remind us of community failure? Yes 34 No 28
5. Do abandoned mine sites provide images for children which are positive or negative? Positive 16 Negative 36
6. Do you feel abandoned mine sites reduce or enhance property values in your neighborhood? Reduce 56 Enhance 3
7. Do you feel that the Mining Museum is enough of a link to our cultural past? Yes 34 No 27
8. Should we attempt to preserve the mine sites close to your home?
   Yes 17 No 44
9. If there is no direct cost to you, would you be in favor of reclamation of abandoned mine sites near your home? Yes 51 No 8

II. Please answer the following questions relating to safety and health aspects.

1. Are any abandoned mine sites in your neighborhood a source of dust?
   Yes 32 No 33 (If yes, would you please list examples?)

   26 surveys had written responses to this question.
2. Do you know of any areas where the ground has settled or where holes have opened up? Yes 24 No 39 (If yes, can you identify the location?)

   20 surveys had written responses to this question.
3. Has there been any runoff or flooding from inactive mine sites in your neighborhood which has affected you?
   Yes 20 No 45 (If yes, would you please list examples?)

   18 surveys had written responses to this question.
4. Do you know of any open shafts or other potentially dangerous conditions such as unsafe structures on or adjacent to inactive mines in your neighborhood? Yes 28 No 37 (If yes, would you please identify the area?)

   28 surveys had written responses to this question.

III. Below, please list any concerns or comments regarding abandoned mine sites not covered above.

24 surveys had written responses to this statement.

Name ______________________ Address ______________________

How Long Have You Lived at This Location? ______________________

Housing Characteristics in Butte-Silver Bow

	Montana	Butte-Silver Bow
1. Year-Round Housing Units		
a. 1980	315,015	16,031
b. 1970	240,304	15,586
c. 1960	220,544	17,790
2. Median Value of Owner-Occupied Units		
a. 1980	$46,500	$31,600
b. 1970	14,000	11,200
3. Renter-Occupied Units		
a. Median Contract Rent (Monthly)	$165.00	$110.00
b. Median Gross Rent (Monthly)	n/a	$149.00
4. Owner Housing Costs, 1980 (Monthly)*		
a. With Mortgage, Median		$302
b. Without Mortgage		116

*Sum of payments for real estate taxes, property insurance, utilities, and regular mortgage payments on one-unit structures of less than 10 acres; excludes mobile homes and trailers and units with a commercial or medical office on the property.

Source: Census and Economic Information Center, Helena, Montana, Montana County Profiles, Silver Bow County, 1983.

APPENDIX F

FINAL SOILS REPORT

COMPREHENSIVE RECLAMATION OF ABANDONED HARD ROCK MINE SITES IN THE URBAN AREA OF BUTTE, MONTANA

for:

Abandoned Mined Land Bureau
Montana Department of State Lands
and
Hydrometrics

by:

William M. Schafer
Schafer and Associates
8601 Panorama East
Bozeman, Montana 59715
(406) 587 9377

date:
March 13, 1984

EXECUTIVE SUMMARY

An investigation of the soil chemical and physical characteristics of waste dumps and tailings in the Butte metro area was performed. Waste materials in the Butte area pose an imminent threat to public health and safety. The following potential pathways of health risk were identified :

1) Air quality degradation by fugitive dust from
    a) Clark tailings
    b) Eroded sediment from waste dumps deposited on streets and entrained by vehicle traffic.

2) Structural instability of dumps or inadequately sealed shafts.

3) Water quality degradation of Silver Bow Creek through contamination of Butte storm drainage by erosion from the waste dumps. Silver Bow Creek has been designated a "superfund" site indicating that the water quality problem constitutes a public health risk. Contaminated water may also carry trace elements onto adjacent city lots where they may accumulate in home gardens.

4) "Direct exposure" risk or risk of intentional or unintentional ingestion or respiration of contaminated soil while at a waste site. The threat of lead accumulation is of greatest concern in the area.

Study of existing characteristics of the wastes indicated that three broad groups of waste materials are found in the Butte metro area; acid waste dumps, neutral waste dumps, and tailings. Acid and neutral wastes may be mixed at a single site but are readily distinguished on the basis of surface color. Tailings materials are found at the Clark tailings pond.

A detailed review of reclamation techniques was performed in order to identify the best available methods for mitigation of the health risk posed by the Butte wastes. Recommended reclamation practices were formulated for each group of wastes.

EXISTING CONDITION

The Butte area has a long history of underground mining, open pit mining, and associated milling. The total length of workings below the city of Butte is estimated at 3,000 miles. The resultant surface waste rock dumps, low grade ore stockpiles, and tailings deposits pose an imminent threat to public health and safety. In addition to the safety hazard associated with poorly sealed mine shafts and unsecured buildings, the public health threat from water quality contamination, direct exposure and air pollution are also severe.

More than 100 inactive mines and waste dumps occur within the Butte city limits or immediately north of Butte. Because of the area topography, runoff from these sites often runs across city streets and into the storm sewer system. Effluent from the storm sewer system contributes to the metal loading of Silver Bow Creek , a designated "Superfund" site. Sediment flowing across city streets is entrained into the atmosphere by vehicle traffic. Access to waste areas by children increases the threat of exposure to excessive heavy metals (Figure 1).

Contamination Pathways

Waste dumps in the Butte area are typically extremely acid, and have excessive amounts of trace elements. Waste dumps are steep, barren of vegetation, and are readily eroded. Some dumps consist of surficial waste rock and have not developed low pH, but are barren due to steep slopes and low water-holding capacity

of the material.

Figure 1. Steep acid Anselmo waste dump with eroded sediment crossing street and entering storm sewer system.

The high sulfide content of waste materials causes a low pH to develop as a result of oxidation. The subject of acid production, abatement, and treatment has been discussed extensively in the literature (Caruccio 1968, Caruccio and Geidel 1978, Geidel 1979). In this review, only the salient points concerning iron disulfide oxidation will be summarized.

Acid production in sulfide wastes and tailings has long been

associated with pyrite oxidation. Microorganisms greatly speed the reaction rate in most environments. For every mole of pyrite oxidized, four or more moles of acidity are produced depending on the reaction pathway (Caruccio and Geidel 1978). The net effect of pyrite oxidation depends not only on the quantity of pyrite, but also its crystal form, particle size, trace metal components, , on the quantity of acid-neutralizing carbonates in the system (Sobek et al. 1978), the pH, oxygen supply, relative humidity, and on the microbial populations present.

Acid is produced by pyrite oxidation through a complicated reaction pathway:

$$FeS_2 + 7/2\ O_2 + H_2O = Fe^{+2} + 2H^+ \tag{1}$$

$$Fe^{+2} + 1/4\ O_2 + H^+ = Fe^{+3} + 1/2\ H_2O \tag{2}$$

$$Fe^{+3} + 3\ H_2O = Fe(OH)_3 + 3\ H^+ \tag{3}$$

$$FeS_2 + 14\ Fe^{+3} + 8\ H_2O = 15\ Fe^{+2} + 2\ SO_4^{-2} + 16\ H^+ \tag{4}$$

Acid forms from oxidation of sulfide to sulfate and also ferrous iron (Fe II) to ferric (Fe III). Ferric iron acts as a catalyst in pyrite oxidation (Singer and Stumm 1968, Smith et al. 1968) which accounts for the ability of microorganisms which convert Fe II to Fe III to speed pyrite oxidation.

Pyrite oxidation is also affected by a number of environmental conditions. Oxygen is required for pyrite oxidation to occur. Oxygen diffusion in water is several orders of magnitude slower than in air. As a result, pyrite oxidation occurs most rapidly in moist aerobic sediments. As long as the relative humidity in the soil atmosphere was near 100 %, pyrite oxidation was unchanged (Smith et al. 1968). Even seemingly dry

soils have relative humidity of 99 percent (Hillel 1980).

Pyrite oxidation is extremely slow in submerged sediments as long as the ground water with which they are in contact is low in dissolved oxygen. Hamilton and Fraser (1978) recommended flooding as a permanent solution for management of sulfide-rich tailings in Canada. They found little pyrite oxidized during 32 years of submersion.

Caruccio and Geidel (1978) found that fine-grained pyrite reacted more rapidly than coarse pyrite which was thought to be a result of the greater surface area of the fine particle sized material. However when crystalline pyrite was ground to the same size as naturally-occuring fine-grained pyrite (framboidal), litle oxidation occured. Hence the crystal structure appeared to be the most important factor influencing pyrite oxidation. Little or no framboidal pyrite (which is typical of marine sedimentary environments) is expected to occur in waste dumps or tailings, unless secondary pyrite has formed in submerged tailings.

Deckler (1982) found that fine-grained mine waste from Montana oxidized less than coarse waste in a study of inactive mine waste. Deckler concluded that most of the fine grained pyrite had already oxidized in the 80-year-old wastes. Very little of the total pyrite reacted in the weathering study presumably due to insoluble iron oxides coating the pyrite surfaces thus slowing reaction, or due to the slow reaction kinetics (Singer and Stumm 1968).

The potential net acidity that can form from a given amount

of pyrite is estimated from the acid-base balance test (Sobek et al. 1978, Smith et al. 1976). The acid-base balance is a measure of the net acid-producing or neutralizing capacity of sediment. For each one percent total sulfur measured, a lime requirement of over 50 tons per acre results (to neutralize the acidity). Silver Bow Creek sediments are not expected to have any appreciable neutralizing capacity so that pyritic sulfur should be an accurate index of potential acid-producing potential.

Geidel (1979) and others have shown that in sediments with a mixture of pyrite and neutralizing materials, that the frequency of flushing by water influences the pH of AMD. In sediments with ample carbonate and rapid water flux, the carbonate which equlibrates quickly with water readily neutralizes acid produced. Pyrite oxidation is kinetically slower than carbonate equilibria but solubility is far higher. As a result, sediments with infrequent flushing will develop water with a low pH despite an abundance of carbonates.

Effectiveness of a number of methods of analysis for inorganic sulfur have been seriously questioned (Dacey and Colbourn 1979). Sulfur, due to its extremely reactive nature is among the most difficult of elements to analyse in a laboratory setting. The primary inorganic forms of sulfur in tailings are expected to be sulfate, and a variety of sulfides predominantly but not exclusively pyrite. The standard method for pyritic sulfur determination was developed for coal analysis (Sobek et al. 1978) and assumes that pyrite is the only iron-or sulfur-containing mineral which can be digested by weak nitric acid.

These assumptions are not likely to remain valid for waste or tailings materials.

Dacey and Colbourn (1979) evaluated a number of currently used methods for analysis of pyrite in coal mine spoils. They found that several extractants did not react with all pyrite. The recommended method involved treatment with boiling 2*M* HCl to remove sulfate followed by treatment with boiling 2*M* HNO3 to dissolve pyrite. Pyrite content was determined by iron analysis presumably because sulfur from organic matter was liberated by the HNO3 treatment. The HCl treatment would remove iron from iron oxides. This method unfortunately has little potential for use on tailings as many non-pyrite sulfide minerals are expected to occur. Some like pyrrhotite and chalcopyrite contain iron while others like bornite and sphalerite do not.

A novel approach for estimation of potentially oxidizable pyrite was developed by Colbourn (1980). A weak nitric acid extractant was used to extract only reactive pyrite. The results correlated well with sulfate leached from weathering columns which simulated field conditions. Substantial correlation of the method would be needed to verify its use on waste dump materials or tailings.

Erodibility of the waste dumps is another factor contributing to the potential public health hazard. Soil erosion has been extensively studied in an agricultural setting. The Universal Soil Loss Equation (USLE) although not applicable to these materials, potints out the factors which influence soil erosion.

$$A = R\ K\ L\ S\ C\ P \qquad (1)$$

where A is soil loss

R is a rainfall erodibility index

K is soil erodibility

L is slope length

S is slope percent

C and P are crop cover and eros[illegible]rol practices and are equal to 1 in this setting.

The inherent erodibility (K) of the gravelly waste dump soils is very low as the coarse particles are not readily entrained by water. In fact a pavement of small rocks has formed on many waste dumps protecting the site from much further sheet and rill erosion (Figure 2). It is thought that most soil movement on these sites occurs as mass movement during snowmelt when underlying layers are frozen. Tailings are extremely erodible due to their fine sand and coarse silt particle size. Slime layers in tailings are less erodible than sands.

The slope length (L) and gradient (S) are the factors most strongly influencing erosion. Many waste dumps are at their angle of repose (32 degrees) but in some cases their slope length is so short that little erosion has occured. Larger waste dumps like the Alice generally have a severe erosion problem with estimated soil loss at more than 30 tons per acre per year (Figure 3). Tailings surfaces are nearly level, and thus only the edges of tailings have sufficient slope to create erosion problems. Large gullies have crept several hundred feet into the interior of the Clark tailings.

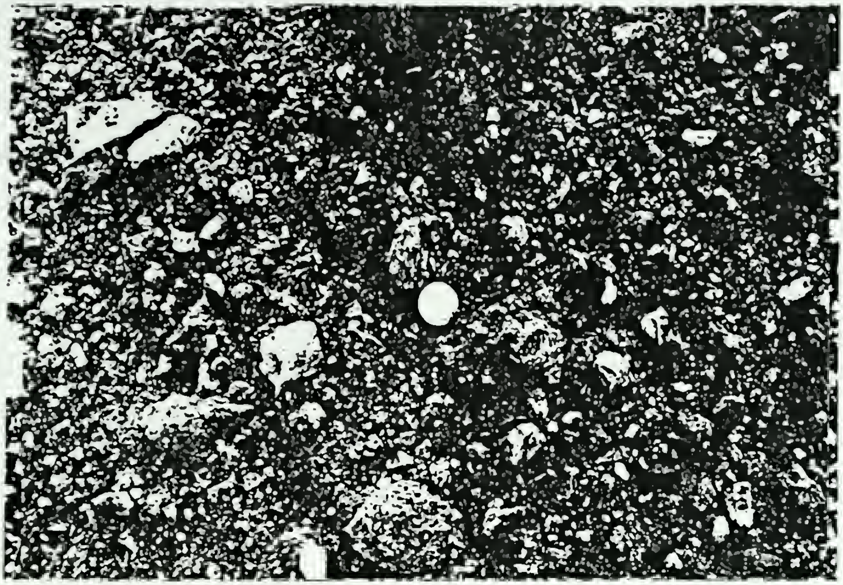


Figure 2. Gravel mulch developed on a waste dump preventing high erosion rates.

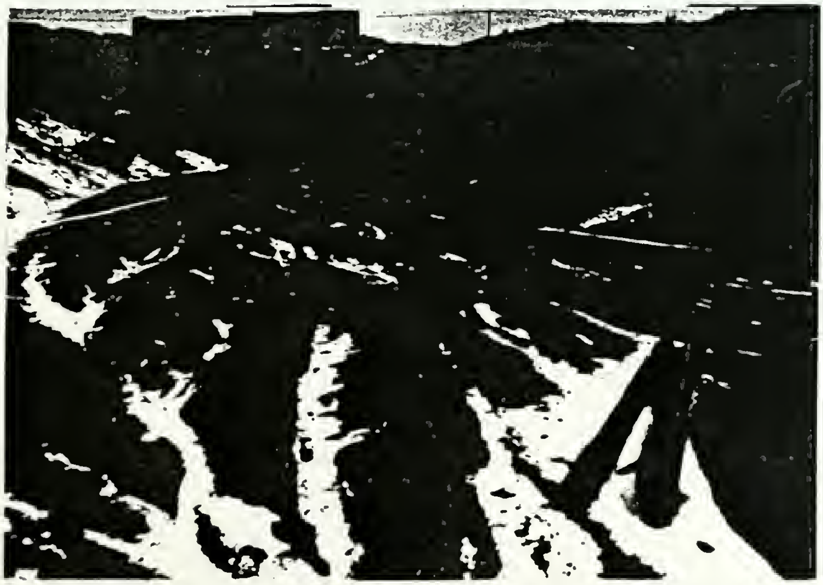


Figure 3. Debris fan of eroded waste dump material near the West Gray Rock site.

Soil Characteristics

An intensive field survey of inactive waste dumps was conducted to assess the potential techniques available for site reclamation. As part of the reclamation feasibility study, detailed soil analyses were collected on a number of samples. In addition, soils data from previous studies (Hydrometrics 1983) were also used. Reclamation techniques were developed to mitigate public health and safety threat from the sites, rather than specifically to improve land productivity or esthetics. Reduction in direct exposure of metal-laden waste, control of accelerated erosion of the dumps by wind and water, and elimination of structural hazards were primary goals of reclamation plan development.

Soil physical data from the Butte samples are presented in Table 1. The chemical characteristics of the samples of waste dumps and tailings are shown in Table 2.

Waste dump materials were characteristically high in rock fragment content (>2 mm size particles) which ranged from 20 to 70 percent by weight. Waste materials ranged from 55 to 85 percent sand, with clay ranging from 3 to 23 percent. Available water-holding capacity of the waste and tailings materials is

Table 1. Soil physical characteristics of the Butte waste materials.

SAMPLE NUMBER	LOCATION	DEPTH (IN)	SAND	SILT	CLAY	ROCKS
			(%)			
1	ALICE DUMP - UPPER SE	0- 6	84.8	10.0	5.2	31.[illegible]
2	MINNIE IRVIN NEAR STREET	0- 6	82.8	10.0	7.2	[illegible]
3	GOLDSMITH GRAY MATERIAL	0- 2	60.9	18.0	21.2	47.[illegible]
[illegible]	GOLDSMITH OXIDIZED	[illegible]	79.8	3.4	17.3	34.1
8	ALICE DUMP LOWER OXIDIZED	[illegible] 6	62.8	18.0	19.2	27.[illegible]
9	DUMP BELOW MT. CON	0- 6	84.8	6.0	9.2	31.9
11	SILVER QUEEN EAST END	0- 4	[illegible]	[illegible]	[illegible]	70.1
13	ANSELMO SOUTH END	0- 3	[illegible]	6.0	7.0	41.6
14	ORIGINAL MINE SOUTH END	0- 4	72.8	14.0	13.2	36.[illegible]
16	[illegible] GRAY MINE	0- 4	62.0	14.0	23.[illegible]	[illegible]
21	[illegible]	0- 4	66.[illegible]	14.6	19.2	64.1
22	BALTIC	0- 4	72.8	16.0	11.2	51.[illegible]
23	COLORADO	0- 4	54.8	18.0	27.2	47.1
BR-100	PLUTUS	0- 24	65.0	14.0	21.0	0.0
BR-103	LITTLE SARAH	0- 24	67.0	16.0	17.0	0.0
BR-106	[illegible]	0- 24	69.0	14.0	17.0	0.0
BR-109	NETTIE NO. 2	0- 1	69.0	15.0	16.0	0.0
BR-113A	TRAVONA	[illegible]	77.0	15.0	8.0	0.0
BR-113B	TRAVONA	0- 24	74.0	13.0	13.0	0.0
BR-117	EMMA	0- 12	63.0	23.0	14.0	0.0
BR-118	COLORADO	0- 24	66.0	11.0	23.0	0.0
BR-143	BUTTE-NEW ENGLAND	0- 24	55.0	22.0	23.0	0.[illegible]
BR-156	KELLEY	0- 24	69.0	17.0	14.0	0.0
BR-158	NEW ERA 334	0- 24	71.0	16.0	13.0	0.0
BR-177	MT. CON	0- 24	72.0	14.0	14.0	0.0
BR-203A	ALICE	0- 6	77.0	16.0	7.0	0.0
BR-203B	ALICE	0- 24	76.0	13.0	11.0	0.0
BR-205	UNNAMED	0- 24	80.0	11.0	9.0	0.0
CLTA-1	CLARK TAILINGS - DARK	0- 24	31.0	59.0	10.0	0.0
CLTA-2	CLARK TAILINGS - LIGHT	0- 24	75.0	19.0	6.0	0.0

expected to be less than 0.5 inches per foot of soil. Soil pH of the samples ranges from 2.2 to 8.5, and electrical conductivity varies from 0.1 to 10.4 mmhos/cm. Averages and ranges of soil properties are shown in Table 3. Concentrations of major cations

Table 2. Soil chemical characteristics of the Butte waste dump materials.

SAMPLE NUMBER	PH	EC	Ca	Mg	Na	SO4	Cu	Fe	Mn	Zn
		mmhos/cm				(mg/l)				
1	7.9	0.2	33.9	8.0	5.1	1.9	0.1	0.1	0.1	0.1
2	7.0	0.2	16.0	4.3	2.8	2.0	0.1	0.1	0.1	0.1
3	8.5	0.1	143.6	46.3	4.0	28.9	0.1	0.1	0.5	0.1
6	3.0	0.6	695.0	26.4	3.0	1504.0	1.8	22.4	61.0	17.3
8	3.2	0.2	184.0	29.0	5.3	479.0	0.1	1.0	92.4	49.7
9	2.6	0.8	537.0	193.0	21.5	1142.0	95.7	416.0	25.3	645.1
11	2.6	1.9	725.0	1565.0	250.2	6088.0	1902.0	9003.0	561.3	7137.5
13	2.3	1.3	1092.0	1271.0	97.2	3899.0	799.0	3838.0	659.8	1630.7
14	4.1	0.2	184.0	19.6	38.4	194.0	53.4	67.3	18.2	105.9
18	2.4	1.5	672.0	576.0	108.0	5114.0	443.6	3730.0	199.1	2480.0
21	2.7	1.4	714.0	1439.0	93.7	4581.0	1463.0	2884.0	282.0	1135.0
22	3.1	0.6	677.0	146.0	26.7	784.0	0.0	0.0	0.0	0.0
23	2.5	1.4	788.0	609.0	146.5	3570.0	0.0	0.0	0.0	0.0
BR-100	6.0	0.8	61.0	7.0	3.0	484.0	0.1	0.0	147.0	3.8
BR-103	6.7	0.5	30.0	6.0	2.0	263.0	0.1	0.0	93.0	0.5
BR-106	2.2	6.9	459.0	23.0	17.0	6880.0	7.1	0.0	242.0	20.9
BR-108	6.8	1.2	286.0	16.0	4.0	713.0	0.1	0.0	1.3	0.4
BR-113A	7.3	0.8	80.0	62.0	10.0	532.0	0.1	0.0	0.1	0.1
BR-113B	7.3	1.2	136.0	111.0	9.0	712.0	0.1	0.0	0.1	0.1
BR-117	2.5	5.0	775.0	154.0	1.0	3360.0	177.0	0.0	91.0	235.0
BR-118	2.6	3.9	531.0	71.0	63.0	3200.0	104.0	0.0	21.3	201.0
BR-143	2.8	10.4	507.0	618.0	1780.0	11300.0	1460.0	0.0	289.0	427.0
BR-156	2.7	4.0	770.0	91.0	2.0	2560.0	52.5	0.0	40.6	160.0
BR-158	2.8	1.6	34.0	23.0	30.0	1100.0	23.1	0.0	7.9	165.0
BR-179	2.8	3.1	669.0	80.0	27.0	2580.0	54.7	0.0	34.3	115.0
BR-203A	3.3	1.8	362.0	47.0	14.0	1490.0	2.9	0.0	128.0	33.3
BR-203B	3.1	2.8	639.0	81.0	21.0	2560.0	3.5	0.0	187.0	70.2
BR-205	6.6	0.5	139.0	23.0	15.0	229.0	0.1	0.0	0.1	0.1
CLTA-1	5.6	6.8	645.0	345.0	6.0	5360.0	0.7	0.0	2375.0	565.0
CLTA-2	2.4	5.7	762.0	42.0	1.0	1700.0	13.3	0.0	109.0	397.0

Table 3. Average and range of soil samples in the Butte area.

	pH	EC	Ca	Mg	SO4	Cu	Mn	Zn	sand	silt	clay
MEAN	4.3	2.3	0424.	249.	2539.	222.	208.	520.	70.2	15.6	14.2
MINIMUM	2.2	.1	16.	4.	2.	<1	<1	<1	31.0	3.4	5.0
MAXIMUM	8.4	10.4	1092.	1565.	11290.	1902.	2375.	7138.	85.0	59.0	27.2

(Ca, Mg, Na) reflects the wide range in soil EC. The EC tends to increase at low soil pH (r=-.43) indicating that pyrite oxidation is largely responsible for salt accumulation. At pH below 3, it

is expected that primary feldspar minerals and clay minerals are beginning to decompose thus releasing Ca, Mg, and Na into solution.

Sulfate is correlated with pH (r=-.75) and EC (r=.60) reflecting its source as a product of pyrite oxidation. A correlation matrix for all soil variables is shown in Table 4.

Table 4. Correlation matrix for soil properties of Butte waste dump and tailings samples.

	pH	EC	Ca	SO4	Cu	Mn	Zn	sand	silt	clay
pH	1.0									
EC	-.43	1.0								
log Ca	-.70	.48	1.0							
log SO4	-.75	.60	.80	1.0						
log Cu	-.82	.42	.68	.65	1.0					
log Mn	-.76	.46	.65	.74	.63	1.0				
log Zn	-.89	.44	.73	.75	.87	.85	1.0			
sand	.0	-.54	-.17	-.33	-.02	-.37	-.19	1.0		
silt	.09	.53	.13	.23	-.09	.30	.16	-.86	1.0	
clay	-.15	.18	.12	.26	.12	.24	.10	-.53	.02	1.0

The relationship of log of soluble copper concentration to soil pH, and log soluble Zn with pH (Figure 4) indicates two distinct chemical groups of materials. A group of low pH samples with soluble copper from 1 to over 100 ppm and soluble zinc from 10 to 7000 ppm contrasts with the high pH soils where soluble Zn and Cu are less than 1 ppm. The frequency distribution of soil

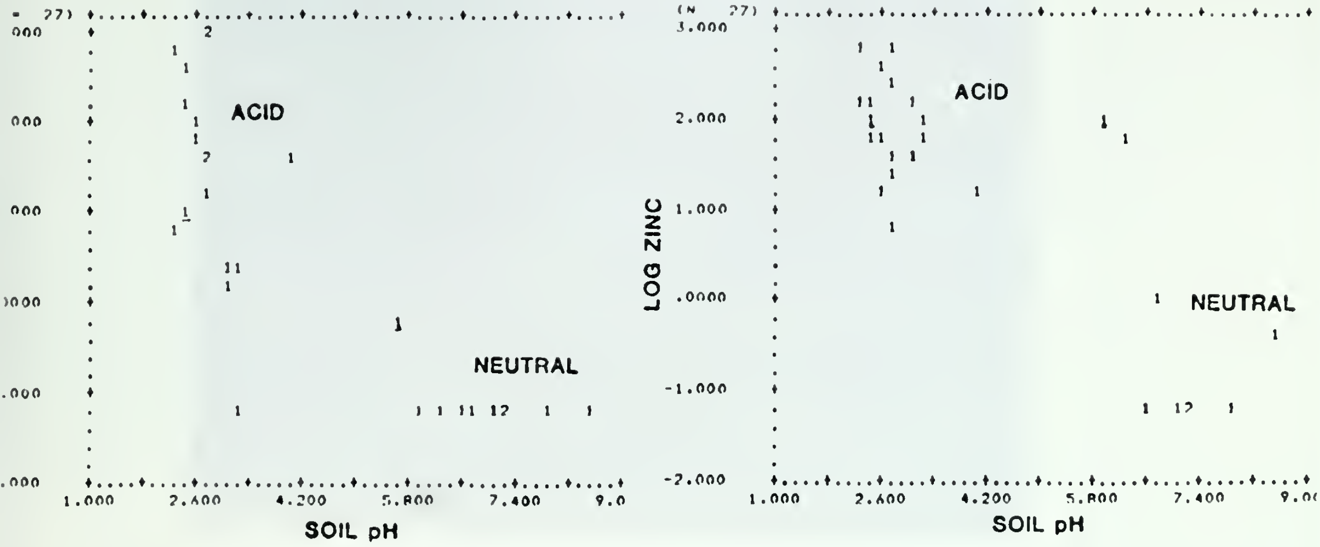


Figure 4. Relationship of log soluble copper concentration with pH (left) and log soluble zinc concentration with ph (right).

pH also indicates two distinct groups of soil materials. Further investigation indicated that high pH samples had gray (low color chroma) colors while low pH samples had the yellowish brown colors (high color chroma) typical of many waste dumps. The yellow color stems from the abundance of iron oxides primarily goethite which has formed as a result of pyrite oxidation. Gray materials reflect their lack of pyrite (Figure 5). It is expected that gray, neutral pH materials were waste rock taken from near the surface and above any zone of appreciable sulfide ore enrichment. The yellowish brown materials (Figure 6) came from deeper underground and represent either unprocessed ore

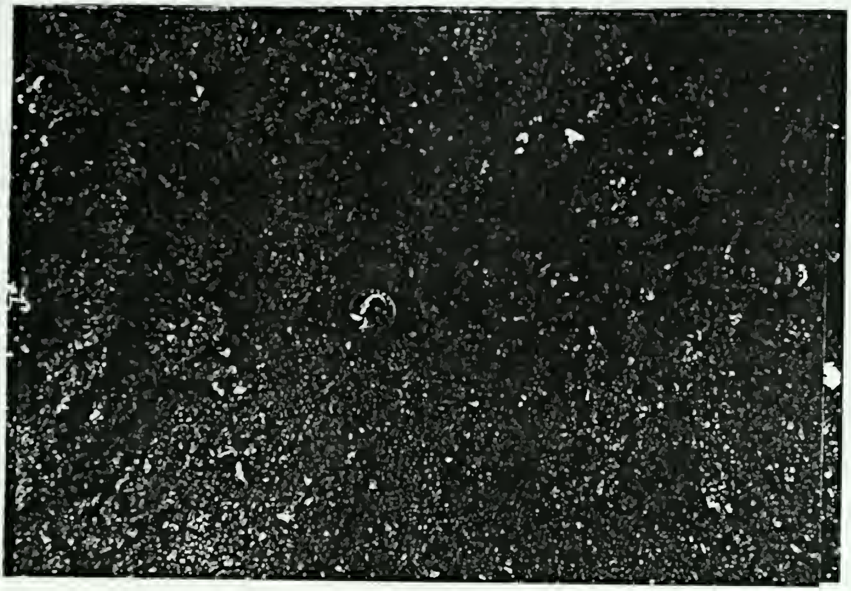


Figure 5. Typical appearance of neutral gray waste materials.

Figure 6. Typical appearance of oxidized acid yellowish brown wastes.

stockpiles or low grade waste. The field characteristic of color is an excellent predictor of soil pH and metal content in the Butte area. It was found that gray and yellow wastes were present in variable mixtures within many of the waste dump areas (Alice, Goldsmith, Kelley, Grayrock). Field inspection of surface color can be used as a reliable means of identifying acid and non-acid materials during project reclamation.

A third distinct group of waste materials was also indicated in the Butte area; the Clark tailings. Tailings materials were distinguished from underground mine waste by the tailings lack of rock fragments, and their higher silt content. Location of tailings materials in a flat-topped tailings impoundment makes their field identification simple. Thus there are three distinct types of waste materials in the Butte metro area each with a unique set of related problems, and required reclamation approaches. These consist of 1) acid waste dumps, 2) non-acid waste dumps, and 3) tailings.

Acid Waste Dumps are the dominant waste materials in the Butte metro area comprising around 60 percent of the total waste. They are characterized by a pH of 2 to 4, EC of 1 mmho/cm or higher, excessive levels of soluble copper, manganese, and zinc which would prohibit plant growth, and distinctive yellowish-brown surface color. Most waste dumps are steep with the slope base either near a street or building often held by a wooden retaining wall. The tops of many dumps are relatively flat, and often they grade at their upslope side into the existing landscape. Acid wastes have from 60 to 85 percent sand and 30 to

70 percent rock fragments making their water-holding capacity less than 0.5 inches per foot of soil depth. Proximity of the dumps to buildings and streets, their slope gradient and slope length, and their accessibility to children are the primary non-structural safety hazards.

Non-Acid Waste Dumps are less common than acid dumps, but can be mixed in occurence with them within a particular site. They comprise about 15 percent of the total waste in the project area. Non-acid dumps have a pH from 5.5 to 8.5, have 60 to 85 sand and 20 to 60 percent rock fragments making their water-holding capacity less than 0.5 inches per foot. They are generally barren of vegetation due to their steep slope, lack of available water, and low nutrient status. These dumps do not constitute a direct health threat except where they are mechanically unstable or present a structural hazard like an open pit or mine shaft. The close association of non-acid and acid materials at many sites will necessitate their reclamation however. Use of non-acid materials to isolate or bury acid waste should be considered as a possible component of the reclamation plan.

Tailings in the project area are confined to the Clark tailings pond at the southwest edge of Butte. Historically, routing of surface water across the Clark tailings has resulted in severe erosion and gullying of the tailings. Flood control structures have been installed (Hydrometrics, 1983). Tailings differ from waste dump material in that they lack rock fragments and are composed of alternating layers of medium sand and clay

and fine silt (slime). The upper part of the Clark tailings are finer grained than the lower part reflecting a change in the milling method. The upper clayey dark colored tailings had a pH of 5.6, an EC of 6.8 and excessive levels of Zn and Mn. The lower light sandy tailings had pH of 2.4, and an EC of 5.7 with high Cu, Mn, and Zn. The stratified nature of the tailings makes them poorly drained and may prevent rooting. Perched water tables may form in the tailings in the early spring. The primary health hazards associated with the Clark tailings stem from the potential air quality concerns and the unsecured nature of the site. Wind erosion and fugitive dust from the the tailings is a problem. In addition, use of the site for off road vehicle and motorcycle use creates a local dust problem which could lead to chronic overexposure to toxic trace elements.

CONTAMINATION HAZARD

Water Quality

Contamination of surface and ground water may not be perceived as a potential health threat to citizens of Butte since the city water supply would not be contaminated. However, polluted surface water entering the storm sewer system discharges into Silver Bow Creek which has been designated a "superfund" hazardous site due to its elevated levels of trace elements. Superfund sites are perceived by the US EPA to constitute a threat to public health or safety as do abondoned mined land (AML) sites. Metal-laden acid surface water can also carry dissolved or suspended sediments onto adjacent areas thus enlarging the contaminated zone around the waste dumps. In many cases runoff from the sites has lead to a build-up of metals in adjacent yards or playfields used by children for recreation or for home gardens. Either of these uses could tie surface water degradation to human uptake of metals.

Direct exposure to waste or tailings material can lead to excessive metal accumulation by humans especially for metals which are accumulated in biological systems like lead. At least three mechanisms of human uptake have been identified including respiratory, dermal contact leading to unintentional ingestion , and pika. Respiratory uptake of metals in fugitive dust is a problem even in off-site areas. Direct entrainment of windblown materials is uncommon on the waste dumps due to the coarse

texture, uneven surface, and broken topography of the sites. Tailings are susceptible to direct entrainment during high winds, however. A second mechanism of sediment entrainment involves deposition of wastes on city streets by water erosion, subsequent drying of the material and fugitive dust generation by vehicle traffic (Figure 7 and 8). Use of the waste site for recreational, dirt-bike, or off-road vehicle use exposes the public to chronic high levels of metals in the dust. Dermal contact has been found to be the primary mechanism of lead uptake by lead mill workers and their family members. Small amounts of dust carried on hands or clothing can be inadvertently consumed or respired. Dermal contact is especially hazardous for children playing on waste dumps or adults using the site for motorcycle and off-road vehicle recreation (Figure 9). The final mechanism of metal uptake by direct contact is pika, or the intentional consumption of soil material by young children. A final concern regarding metal accumulation is uptake of metals from contaminated city gardens. The EPA identified home gardens as a primary source of metal accumulation by humans in contaminated areas.

A number of factors may influence the solubility of a metal in soil including clay content and type of clay mineral, presence of oxides, organic matter level, and the total amount of element present. Metal solubility influences not only plant uptake (as in home gardens) but also the tendency of an element to contaminate surface water, and perhaps also the bioavailability of respired or ingested material. For metals like Cu, Mn, Fe, Zn, Cd, Ni, and Pb, however, soil Eh and pH play a leading role

Figure 7. Erosion from the Little Mina dump entering a residential area.

Figure 8. Erosion from the Mt. Con mine crossing a city street. Notice the lack of area available for regrading the dump.

Figure 9. Recreation area near the Alice Dump.

in determining the forms of each element dominant and hence its availability. For example manganese exists as the insoluble Mn+4 ion in oxidized, neutral pH soils. At low pH or Eh the Mn+2 form which is quite soluble dominates. Other metals like arsenic and molybdenum are anions in soil and thus are affected in different ways by changes in soil pH and Eh. The metals of primary concern as potential contaminants are Cu, Zn, Fe, Mn, Cd, Pb, and As.

Copper

Copper exists in soil as the Cu+2 ion and in various mineral oxides, sulfates, or sulfides depending on pH and Eh (Lindsay 1979). Copper among all the metals has the highest affinity for

organic chelates which suggests that the addition of organic material could reduce copper solubility.

The solubility of a metal cation is governed in part by the abundance of anions with which it forms precipitates. Copper can form a weak hydroxid or carbonate but only at extremely high solution concentration. Under slightly reducing conditions such as can occur under a perched water table in the Clark tailings insoluble Cu2S can form. Copper also has a tendency to become adsorbed onto the surfaces of iron and manganese oxides which form at pH above 4 to 5.

Soil-born copper taken up by mammals can be readily tied up by excessive concentrations of other metals in the soil like iron, zinc, molybdenum or sulfate. As a result copper toxicity from ingestion is seldom reported (Parr et al. 1983). Copper seldom accumulates in garden plants at high enough levels to cause toxic effects because phytotoxicity prevents excessive build-up of plant copper.

Zinc

Zinc exists in soil only as the divalent ion Zn+2. Zinc forms a weak oxide at high solution concentration or at very high pH, and can also form a fairly soluble carbonate (smithsonite). Under reducing conditions, ZnS can form under conditions similar to that required for precipitation of pyrite. Pavanasasivam and Axley (1980) found that in high sulfate soils, reducing conditions tended to lower zinc in the soil solution indicating the precipitation of ZnS. Like other metals zinc is known to

interact with a variety of other minerals, in particular phosphate. In calcareous soils with pH above 7. 5 to 8, complex insoluble carbonates ($ZnCO_3.2ZN(OH)_2$) can form. Zinc like other metals is thought to be adsorbed on the surface of oxides, on clay mineral edges, and to be co-precipitated on carbonates.

The potential threat from zinc contamination either through ingestion, respiration, or food consumption is considered minimal. Excess zinc accumulation tends to reduce copper availability to mammals, but Butte waste materials also have elevated copper levels thus minimizing the potential of zinc toxicity.

Iron and Manganese

Iron and manganese are discussed together because of their similar chemical response in soil. Both metals undergo redox reactions in soil. Iron can occur as ferric (Fe+3) or ferrous (Fe+2), while manganese occurs as the Mn+4 or Mn+2 forms. The reduced species Fe+2 and Mn+2 are very mobile (soluble) in soil while the oxidized species form insoluble oxide minerals. At low soil pH the soluble species are favored but large quantities of Fe+3 can also occur in solution below pH of 4. Sulfides of iron and manganese can form under reducing conditions, especially with the high sulfate content found in the Clark tailings.

The tendency of iron and manganese oxides to form in surface water and to adsorb other metals has a strong influence on water quality. Adsorption of zinc, copper, cadmium or other metals onto colloidal iron or manganese oxide could keep these metals in suspension almost indefinitely.

Iron and manganese are not expected to be directly harmful to humans.

Cadmium, Lead, Arsenic and Other Elements

Cadmium and lead are similar chemically and are highly toxic to biological systems. The common form of cadmium is Cd+2 and lead Pb+2. Both ions are fairly soluble at pH below 4, but form insoluble carbonates at higher pH levels. Lead also forms a sulfate at pH below 4. Under slightly reducing conditions,

cadmium and lead form sulfide minerals. Cadmium is one of the most mobile toxic trace elements, and is extremely toxic at low concentrations making it extremely hazardous. Lead accumulates in the food chain, and presents a particular hazard to mammals due to the potential for soil ingestion.

Arsenic exists in soil as an anion with behavior similar to phosphorus. It is strongly held to soil colloids and oxides. Arsenic is of particular concern in waste materials that are to be limed because its solubility increases with increasing pH. Arsenic is present at high concentrations in the Butte wastes and tailings so liming of the waste could potentially lead to arsenic toxicity. Arsenate can be reduced to arsenite in reduced soils, which can be even more toxic to plants.

Cadmium accumulation through the food chain is of particular concern and has been identified by the EPA (Parr et al. 1983) as the element in sewage sludge most likely to cause adverse human health effects. Food consumption from a home garden is the most critical mechanism contributing to cadmium uptake. Erosion and surface runoff from waste piles must be reduced in order to minimize cadmium accumulation on city lots. Total cadmium content of waste was 2 to 8 ppm in selected soil analyses of the waste samples.

Lead accumulation from dust ingestion and respiration is potentially the most likely pathway to cause excessive trace element accumulation by humans in the Butte metro area. The total lead content of the acid waste dump materials ranges from 400 to 1800 ppm or nearly 0.2 percent lead. Parr et al. (1983)

identified the dust on clothing of lead mill workers as the primary source of elevated blood lead levels in the workers children. Lead exposure from playing on or around waste dumps can lead to chronic problems with excessive lead accumulation particularly among children. The tendency of lead to accumulate in mammals makes it of particular concern to residents of Butte. Use of waste dumps and tailings for recreational motorcycle and off-road vehicle use is suspected to contribute to lead uptake by humans.

In summary, the potential for excessive heavy metal accumulation by humans is by the following pathways: soil ingestion by inadvertent oral contact or intentional ingestion by young children. Respiration of dust-laden air from the Clark tailings or from vehicle entrainment from silted streets may cause excessive lead or zinc uptake. Finally, consumption of vegetables from home gardens may lead to excess cadmium, or zinc uptake. Leafy vegetables and root crops have the most hazard for cadmium accumulation.

Review of Reclamation Methods

Removal of waste materials deemed hazardous is perhaps the first reclamation option to consider. At many locations (Alice, Syndicate) an open mine pit lies adjacent to large waste dumps offering an attractive alternative to in-situ reclamation. With short haul distances, it may be more economical to backfill the mine pits than to reclaim the waste dumps. It is anticipated that for most waste dumps, and for the Clark tailings that in-situ reclamation would have to be implemented.

Regrading of the waste piles will be a necessary component of reclamation for most sites that are actively eroding. The primary constraint to regrading the materials will be the space required to reduce slopes without impinging on streets, houses, buildings, or recreation areas. Slope reduction could be used in conjunction with erosion control structures like terraces and diversion ditches to reduce soil erosion from hazardous sites.

Use of protective covers such as gravel mulch, wood by-products or straw have been used to reduce wind erosion and water erosion of tailings materials. Although these treatments are effective at reducing water and wind erosion it has been found that leaching through surface amended tailings systems is not reduced. As a result, simple surface amendments of tailings or waste areas are not deemed suitable.

Direct seeding of acid tailings and wastes has been attempted by a number of investigators with varying success. Use

of metal tolerant species has allowed workers in Great Britain to vegetate acid spoils without use of amendments (Wainwright and Woolhouse 1975). Accumulation of metals by tolerant species might make such sites hazardous for livestock or wildlife utilizing the site.

Use of high rates of lime and fertilizer have usually been used to enable direct seeding of acid wastes. Farmer et al. (1976) revegetated waste dumps at the Blackbird Mine in Idaho with and without applied cover-soil. Lime rates of 800 to 1600 pounds CaO were used. Plots without cover-soil had poor cover after 2 years, and acid spots were developing and killing portions of the stand. Nielsen and Peterson (1972) tried direct seeding tailings in Utah and found best success with greater tha 100 tons per acre of lime. It was found that at high lime rates, neutralization of acid led to acumulation of sulfate and bicarbonate salts so that most vegetation was damaged. The excess water in the tailings was in part responsible for salt accumulation at the soil surface. Research by Geidel (1979) suggests that under near-saturated conditions that even high rates of lime will be ineffective at reducing acid production. High lime rates used on the Anaconda tailings have been consumed by acid seeps along the tailings edges, again indicating the need to prevent saturated conditions in tailings in order to allow lime to neutralize acid produced.

Watkin and Watkin measured the lime requirement of a number of Canadian wastes and tailings using greenhouse tests. Lime needs ranged from 25 to over 125 tons per acre, yet even with

high rates of applied lime adequate revegetation could only be accomplished with use of cover-soil. The low water-holding capacity does not favor establishment of a vigorous plant community. In addition, the depth of lime incorporation determines the effective rooting depth of plants. Lime can only be thoroughly mixed through the top 8 to 10 inches of the soil using agricultural implements.

As roots penetrate the limed layer, they will accumulate heavy metals from the underlying untreated waste. Johnson et al. (1977) found that seeded vegetation performed well until roots penetrated the acid waste materials in 2 to 3 years at which time stand vigor decreased.

It could be concluded that direct seeding has application on low sulfur waste where no high water tables exist and where limited vegetative cover and production are acceptable. Under these conditions the cost of direct seeding might be less than other revegetation techniques. Typical cost for lime (150 tons per acre at $30) would be $4500 or more, for vegetation, fertilization, planning, and implementation would be $2000, for an expected cost range of $6500 to $12000 per acre depending on sulfur content.

Use of cover-soil has been recommended by a number of investigators (Watkin and Watkin 1982, Farmer et al. 1976, Harwood 1979, and Johnson et al. 1977). Schafer (1979) rated the soil characteristics determining suitability for use as cover-soil. However, establishment of a stable vegetative cover rather than high productivity is the goal of most revegetation efforts

on mine wastes. As a result, a broad spectrum of soil materials should be considered suitable for use as cover-soil.

Barth (1984) found that vegetation response increased with increasing soil depth placed over acid waste to 60 inches. However satisfactory ground cover would be expected at soil depths of 14 to 18 inches. Johnson et al. (1977) found that even with up to 36 inches of applied cover-soil that vegetative stands lost vigor when roots reached the untreated waste after 2 to 4 years. Liming of the cover-soil waste boundary may mitigate this adverse effect. Most investigators found that a functional stand was maintained on all soil depths of greater than 12 to 18 inches. It appears that isolation of the waste may be required on extremenly acid sites. Barth and Martin (1981) suggested the use of a gravel "capillary" barrier below cover-soil to prevent upward movement of soluble salts into the soil layer.

A combination of either cover-soiling with liming or of liming and direct seeding will likely be necessary for Butte area waste clean-up. Establishment of a vegetative cover will protect the surface from erosion while reducing or eliminating deep percolation of water.

Characteristics of waste dumps or tailings and of surrounding cover soil materials must be identified in order to develop suitable reclamation plans. An approach to cover-soil application termed "layering" can provide a suitable root medium while reducing recharge of the tailings or upward flux of contaminated water (Figure 10). The medium-textured non-acid cover-soil provides an adequate root growth media. The sand

layer reduces deep percolation of water and increases plant-available water in the cover-soil (Hillel 1980). The clay would prevent loss of the sand into the gravel and further reduces percolation or root penetration into the toxic waste materials. The lime gravel would neutralize an elevated water table, and provide a pathway for lateral seepage of excess water.

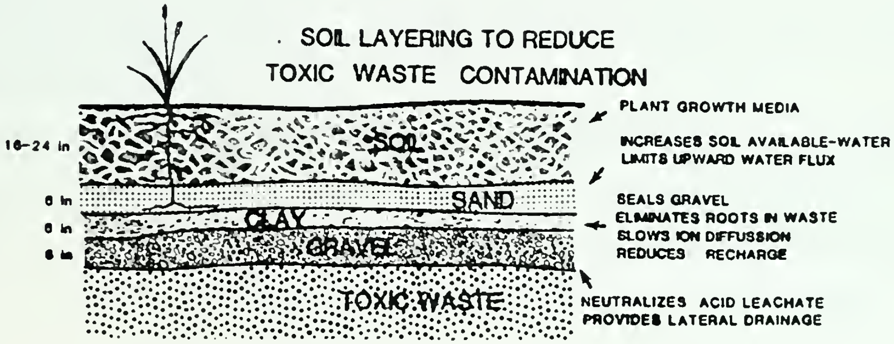


Figure 10. A soil layering system to prevent tailings recharge or soil contamination.

Liming of acid tailings materials is almost certain to be a necessary aspect of project reclamation. It is often difficult to identify accurate lime rates for use on materials which contain pyrite. The SMP buffer soil test for lime requirement (Shoemaker et al. 1961) will almost certainly underestimate total lime needs for pyrite-rich materials, but the acid-base balance approach (Sobek et al. 1978) will frequently over-estimate total lime requirement. Various methods for lime incorporation should also be investigated as the effective root zone is likely to be

limited by the practical depth of lime incorporation. Use of agricultural tillage equipment for incorporating lime materials is almost certain to result in more adequate incorporation of lime than the common practice of ripping by bulldozers.

Lime is used widely in the midwestern and eastern U.S. for correction of acid pH in agricultural soils. The neutralizing capacity of various grades and standards of lime are well documented in the literature. Where the use of lime is necessary, specifications should always be made of the type and fineness of product to use.

Two factors affect limestone effectiveness, its calcium carbonate content and its fineness. Liming materials are evaluated on the basis of their "calcium carbonate equivalent", the neutralizing power of pure powdered $CaCO3$, rated at 100.

Finely ground liming materials react quickly with the soil to reduce acidity, while large particles react too slowly to be effective. Use the table below as a guide to the relative effectiveness of various particle sizes. Typical limestone materials have a lime equivalent of about 1,000 pounds per ton. All lime recommendations must be adjusted for the lime equivalent of the material used.

Table 5. Relative neutralizing capacity of different fineness grades of lime.

Mesh size(#/inch)	Effectiveness
larger than 4	0 %
4 to 8	10 %
8 to 60	40 %
smaller than 60	100 %

Schafer developed a pollution control method called the "treatment trench system" with specific application for tailings and thick over bank sediment deposits. The treatment method outlined (Figure 5) will dewater tailings and sediment deposits, treat and mitigate the acid nature of the effluent, and reduce wind erosion hazard. The trench system can be used alone or in combination with cover-soiling and revegetation. Treatment trenches can also be used with a series of wells installed to draw down shallow ground water beneath the tailings or sediment deposits. Well discharge an also be run through the trench before discharge to the creek. The treatment trench system consists of a series of trapazoidal drainage ditches (Figure 11) placed in the tailings or sediment which will lower the water table. Trench sidewalls and bottoms are veneered with a layer of coarse limestone aggregate. The limestone bed will neutralize effluent collected by the drainage system. The design of the drainage system allows for addition of new gravels or replacement of spent gravels as heavy metal precipitates begin to clog the limestone bed.

Drainage trenches should be constructed to the base of the tailings or sediment deposits in order to collect all contaminatated water. The treatment trench along the tailings perimeter should be constructed between the tailings deposit and the outer dike. This will allow water to readily drain laterally from the tailings or sediment deposits. This design feature recognizes that the lateral or horizontal permeability of tailings of sediments is far greater than the vertical

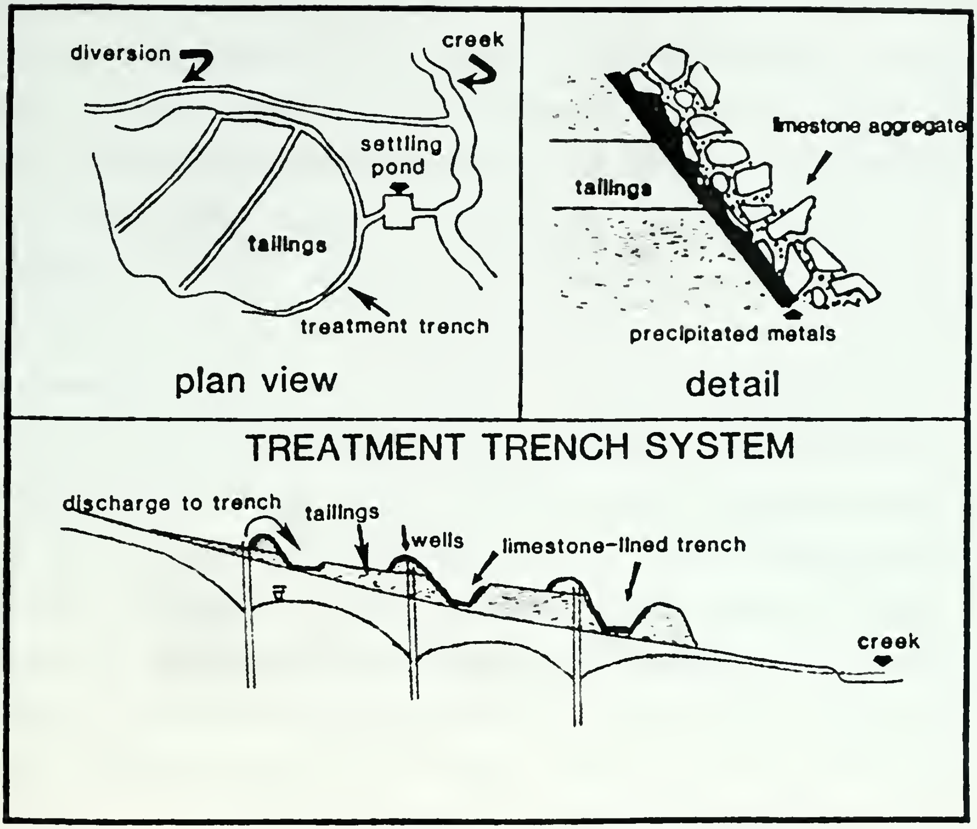


Figure 11. Detail of the treatment trench system.

permeability due to the stratified nature of the deposits. Even in shallow ground water areas dewatering of the tailings using this drainage system should decrease the hydraulic head in the tailings system sufficiently so that very little ground water recharge occurs through the tailings.

It is anticipated that as water drains into the drainage system that the acid effluent will be neutralized causing formation of a crust of iron oxides and other heavy metal

precipitates. As this precipitate layer builds in thickness it will eventually coat all of the gravels on the sidewall and base of the drainage trench. Placement of new gravels over the spent gravel should renew the neutralizing capacity of the drainage system. When the crust thickness of the precipitates becomes too thick and impedes hydraulic conductivity then spent gravels will be removed with a grader and new gravels will be replaced. Gravels to be placed in the drainage system can be stock-piled on the upslope side of the trenches. These gravel birms will slow the wind velocity over the tailings surface thus reducing wind erosion. The gravel birms have the added advantage that they will not themselves be erodible as are birms constructed of tailings material. This drainage design can be used in conjunction with cover soiling and revegetation of a tailings surface. Effluent from the drainage system can be collected to a central treatment facility if water quality is not sufficient for discharge to Silver Bow Creek. Although feasibility studies will be needed to identify the treatment capacity of the trenches, it is anticipated that effluent will be of sufficient quality to discharge directly into Silver Bow Creek throughout most of the year.

Preliminary Reclamation Plan

Acid Waste Dumps constitute the most widespread threat to public health and safety in the Butte area. Their acid nature, high metal content, availiability to public use, and steep erodible surface configuration make them a dominant source of excess heavy metals in the Butte metro area.

The feasibility of removal of waste dumps should be investigated on a site by site basis. Where economic contraints would allow dumps to be hauled away ,for example into an adjacent mine pit, environmental impacts from the site would be minimized. It is expected that underlieing soil would be contaminated with acid leachate from the dumps making lime treatment necesarry. Lime applied at 5 tons per acre and incorporated to 6 inches in depth would allow the site to be revegetated.

Reclamation of remaining waste dumps should be reclaimed on a priority basis where health threats from air quality, structural hazards, direct exposure, and water quality contamination are all considered. The water quality and exposure hazard of each of the dumps indicated to pose an air quality or structural hazard are noted in Table 6. The water quality hazard was ranked from 1 to 5 based on the amount of acid dump materials at the site, slope gradient, surrounding drainage configuration, and proximity to the storm drainage system. Direct exposure threat was ranked from 1 to 5 based on the amount of acid materials at the site, proximity to neighborhoods, and evidence of site use for recreation.

Table 6. Water quality and direct exposure hazard of the sites deemed to pose an air quality or structural hazard.

SITE		HAZARD RATING				CONFINED:
	WASTE TYPE	AIR QUAL.	SAFETY	WATER QUAL.	DIRECT EXPOSURE	DIFFICULT TO REGRADE
CLARK	TAILING	Y	1	5	5	
BELMONT	ACID		4	3	2	
OTISCO	ACID		4	3	2	
COLORADO	ACID	Y	4	5	4	Y
ROY	-		3	-	-	
HESPERUS	ACID		3	2	2	
PARROTT	-		4	-	-	
ORIGINAL	ACID	Y	5	5	3	Y
LITTLE MINA	ACID		4	5	4	
MT.CON	ACID	Y	4	5	3	Y
CLEAR GRIT	-		5	-	-	
MOONLIGHT	-		4	-	-	
BUFFALO		Y	5	-	-	
BENHAM	ACID		3	3	3	
STEWARD	ACID		4	4	3	Y
RISING STAR	ACID		4	3	2	
ALICE	MIXED		5	5	4	
GOLDSMITH	MIXED		3	3	3	
PAYMASTER	ACID		3	3	5	
EVELINE	MIXED		3	2	3	
VENUS	MIXED		3	2	3	
MOOSE	ACID		4	3	3	
DIAMOND	ACID		5	3	2	
MAGNA CARTA	ACID		4	3	4	
W.GRAY ROCK	ACID		5	4	3	
VALDEMERE	-		-	-	-	
BELLE/BUTTE	MIXED		4	2	2	
MARY LOUISE	-		4	-	-	
ARDSLAY	-		3	-	-	
BONANZA	NEUTRAL		4	2	3	
TRAVONIA	NEUTRAL	Y	4	2	3	
OPHIR	NEUTRAL	Y	3	2	3	
EMMA	ACID	Y	5	5	4	
LEXINGTON	ACID		4	4	4	Y
W. GAGNON	ACID		4	5	5	Y
SYNDICATE	ACID		4	4	3	
MISSOULA	ACID		3	3	3	
ANSELMO	ACID	Y	4	5	4	Y

Substantial regrading will be required on most waste dumps to reduce erosion sufficiently to enable vegetation to become established in replaced cover-soil materials. Slope gradients should not exceed 20 percent on long slopes (>500 feet) or 25 to 30 percent on shorter slope lengths. At many sites there will be insufficient space to extend slopes the required amount to reduce slope gradient adequately. On these dumps a series of terraces should be constructed to collect runoff and convey it down a rock-lined channel or drop structure. A similar technique was used at the Continental Dump east of Butte with considerable success.

The key to adequate reclamation of the acid waste dumps is in providing an adequate depth of non-toxic cover material with sufficient water-holding capacity to create a viable plant root zone. Review of literature revealed that direct seeding of tailing or waste dumps was seldom successful Direct seeding failed after up to three years prior to planting for the following reasons: 1) lime requirement underestimated, 2) inability to incorporate lime to a sufficient depth, 3) inadequate water-holding capacity, 4) accumulation of metals from the underlying subsoil layers, and 5) development of acid seeps at the surface.

The assumption underlying the cover soil depth recommendation is that a permanent vegetative cover is required to reduce percolation of leachate through the waste, and to reduce surface runoff and erosion. The goal of revegetation is to help reduce public health threat and not to maximize

vegetative production.

It is felt that a tradeoff exists between lime application and cover soil depth. Barth and Martin (1981) found that toxic constituents contaminated the lower 4 to 6 inches of applied cover-soil. In order to provide an adequate root zone depth, 24 inches of cover soil would be required. Cover soil depth could be reduced to 18 inches if 15 tons per acre of lime were placed at the soil/spoil interface. Cover soil depth of 12 inches with 60 tons per acre of lime at the interface worked in to the spoil 6 inches would also provide an adequate root zone. Table 7 shows the relative costs of each cover soil method for varying soil and lime costs. At a cost ratio of 17.8 or less (lime cost $ per acre / soil cost $ per yard), then option 3 is most economical. At a cost ratio of 53.3 or greater, then option 1 would be preferred. Option 2 should be used for a cost ratio of 17.8 to 53.3.

Table 7. Cost of cover soil techniques for Butte wastes at varying soil and lime costs.

COSTS SOIL $/yd	 LIME $/ton	OPTION 1 24" soil	OPTION 2 15 t lime 18" soil	OPTION 3 60 t lime 12" soil
			($/acre)	
1	40	3200.00	*3000.00	4000.00
4	40	12800.00	10200.00	*8800.00
1	80	*3200.00	3600.00	6400.00
4	80	12800.00	*10800.00	11200.00

* least cost option

Use of locally available cover soil materials should be investigated to reduce soil costs. Soil should have a water-holding capacity of at least 1.5 inches per foot of soil depth (12.5%), and should rank as fair or good in quality according to Schafer (1979), Table 8. Poor quality cover soil can be used where the property causing the poor ranking is treated to improve its adverse effects.

Table 8. Topsoil quality guidelines from Schafer (1979).

Factors Affecting Suitability of Soil Material	Good	Fair†	Poor‡
Texture class	vfsl, fsl, sl, l, sil	lfs, ls, cl, scl, sicl	s, c, sc, sic
Moist consistence	vfr, fr	lo, fi	vfi, exfi
EC (mmhos/cm)	<4	4–8	>8
ESP	0–5	5–15	>15
pH	5.6–7.8	4.5–5.6; 7.8–8.4	<4.5, >8.4
Stoniness class	0	1	2–5
Available water	>10	5–10	<5
Rock fragments (%)	<15	15–35	>35
Saturation water (%)		25–80	<25; >80

---

†Mitigation of adverse properties will increase reclamation potential.
‡Materials rated as poor may be suitable as topsoil only if adverse factor can be treated.
§Numbers relate to references at the end of this report.

Use of cover soil from the east end of the Berkeley pit should also be investigated. An extensive alluvial fan deposit is exposed in the pit wall. Parody and Schafer (1981) investigated the suitability of the alluvium for use as cover soil. They found that the material had a severe crusting problem, but suggested that fall-seeded grasses would emerge before crust stength increased sufficiently to stop emergence.

Cover soil materials should be tested for nutrient element content (N, P, K). It is expected that available cover-soil materials will be low in all elements. A standard fertilizer rate of 20 pounds of N, 100 pounds of P2O5, and 75 pounds of K2O is recommended. Monoammonium phosphate (11-55-0) should be used as the source of N and P2O5 and should be broadcast and incorporated at the rate of 183 pounds per acre. Potassium chloride (0-0-60) should also be broadcast and incorporated at the rate of 125 pounds per acre to provide the 75 pounds of K2O. In addition, 50 pounds of 11-55-0 should be applied with the seed through the seed drill at planting to encourage rapid germination and establishment of the seeded vegetation. The low initial nitrogen rate should reduce weed competition during stand establishment. After seeded vegetation is growing, an additional 70 pounds of nitrogen should be added. Addition of 200 pounds per acre of ammonium nitrate (34-0-0) would be suitable to provide this late-applied nitrogen.

Neutral Waste Dumps are less toxic than acid dumps but may require reclamation when in close contact with acid dumps. The requirement for regrading of neutral dumps is identical to that for acid materials.

Cover soil depth of 14 inches should be sufficient for the neutral dumps. Neutral dump materials could also be used to bury or isolate acid dump materials from applied cover-soil. If soil pH of the gray dump material is less than 5.5 then 2 tons of lime should be applied and incorporated to 6 inches in depth before cover soil application.

Soil fertilizer requirements for the cover soiled neutral waste material are expected to be the same as for acid materials.

Tailings materials require a slightly different approach to reclamation than waste dump materials. Regrading of the tailings is not expected to be required due to the flat configuration of the Clark tailings. Erosion through the middle of the pond has left steep slopes which may require regrading in order to stabilize them.

If air quality is found to be the only significant health threat from the Clark tailings, then applicatiopn of a surface treatment may be sufficient to reduce entrainment of tailings particles. The Anaconda Minerals Company has used a thin veneer of 1/4 inch minus gravel on the Opportunity ponds to reduce fugitive dust with great success. Murray and Okuhara (1980) found that surface mulches do not affect effluent quality. A water budget simulation of drainage through the Clark tailings

indicates that 1.1 inches of drainage would occur under average precipitation through the Clark tailings (Table 9), and that if a mulch layer were applied the drainage would increase to 1.7 inches per year (Table 10). Assuming a 40 acre area of tailings, this amounts to 3.7 acre feet (160,000 cubic feet) of contaminated effluent without mulch and 5.7 acre feet (247,000 cubic feet) of acid effluent with a gravel mulch. If it is assumed that water quality contamination of Silver Bow Creek is a serious concern, then simple surface treatment of the tailings with a gravel mulch is insufficient.

Revegetation of the tailings pond should reduce drainage to zero even in above average precipitation years (Table 11). Cover soil application to the tailings would be required to allow revegetation of the tailings. Water movement observed in tailings is extremely slow which causes perched water tables to form which allows acid materials to rise by capillary action to the soil surface. As a result, the cover soil depths and lime rates recommended for acid dumps should be increased by 50 percent for use on tailings (Table 12). If a 6 inch gravel layer were placed between the cover soil and tailings as a capillary barrier (Barth and Martin 1980), then the same soil depth and lime rates used for acid dumps would be suitable.

Table 9. Water budget simulation for the Clark tailings assuming a bare surface (present condition).

```
SOIL PARAMETERS:                                  BOUNDARY CONDITIONS:
---------------                                   ------------------

     ROOT DEPTH (CM)          = 30                     SOIL WATER(0)= 1.5
     WATER-HOLD.CAP.(CM/CM)= .05                      SNOW(0)        = 0
     TOTAL AVAIL. WATER(CM)= 1.5                      DRAINAGE(0)    = 0
     WATER TABLE DEPTH (CM)= 200

SURFACE PARAMETERS:                               SIMULATION YEARLY SUMMARY:
------------------                                --------------------------

     VEG (0=NON,1=VEG)        = 0                      NOAA PPT         = 32.85
     MULCH(0=BARE,1=1CM,                               ACTUAL PPT       = 26.0041
      2=2CM,3=>4CM.4=VEG)     = 0                      TOTAL PET        = 83.6
     VEG COVER (%)            = 0                     ACTUAL ET        = 24.4677
     RUNOFF CLASS  *          = 1                      AVE SOIL WATER
     SNOW TRAP EFF. (%)       = .4                      AS % RECHARGE= .106048
                                                       DRAINAGE         = 2.27794

--------------------------------------------------------------------------------
* 1=NO RUNOFF, 2=SITE WHERE RUNOFF OCCURS, 3=SITE WITH ACCUMULATION


--------------------------------------------------------------------------------
           * * *  S I M U L A T I O N   S U M M A R Y  * * *
  MONTH        I    PPT    ACT.PPT   SNOW      PET      ETa   SOIL H20 DRAINAGE
--------------------------------------------------------------------------------

               1    1.20    1.02     0.00      2.60     2.60    1.50     0.00
  MAY          2    1.37    1.16     0.00      3.60     0.36   -0.08     0.00
               3    1.68    1.43     0.00      4.20     0.80    0.72     0.00
               4    2.03    2.03     0.00      4.80     4.79    1.35     0.00
  JUN          5    2.36    2.36     0.00      5.50     0.55   -1.41     0.00
               6    1.72    1.72     0.00      6.00     0.60    0.40     0.00
               7    1.18    1.18     0.00      6.40     6.40    1.50     0.02
  JUL          8    0.96    0.96     0.00      6.50     0.65   -3.72     0.00
               9    0.89    0.89     0.00      6.30     0.63   -3.41     0.00
              10    0.72    0.72     0.00      5.80     0.58   -3.15     0.00
  AUG         11    0.68    0.68     0.00      5.50     0.55   -3.01     0.00
              12    0.71    0.71     0.00      4.60     0.46   -2.88     0.00
              13    1.02    1.02     0.00      3.70     0.37   -2.63     0.00
  SEP         14    1.21    1.21     0.00      3.20     0.32   -1.98     0.00
              15    1.01    1.01     0.00      2.20     0.22   -1.09     0.00
              16    0.85    0.65     0.00      1.70     0.17   -0.30     0.00
  OCT         17    0.77    0.59     0.00      1.50     0.15    0.18     0.00
              18    0.75    0.57     0.00      1.20     0.18    0.61     0.00
              19    0.73    0.45     0.00      0.90     0.48    1.00     0.00
  NOV         20    0.71    0.40     0.00      0.70     0.34    0.97     0.00
              21    0.66    0.37     0.03      0.40     0.23    1.03     0.00
              22    0.61    0.18     0.06      0.00     0.00    1.17     0.00
  DEC         23    0.59    0.18     0.12      0.00     0.00    1.35     0.00
              24    0.58    0.16     0.18      0.00     0.00    1.50     0.03
              25    0.56    0.09     0.25      0.00     0.00    1.50     0.16
  JAN         26    0.54    0.12     0.38      0.00     0.00    1.50     0.09
              27    0.52    0.14     0.47      0.00     0.00    1.50     0.12
              28    0.52    0.15     0.55      0.00     0.00    1.50     0.14
  FEB         29    0.58    0.17     0.60      0.00     0.00    1.50     0.15
              30    0.61    0.18     0.67      0.00     0.00    1.50     0.17
              31    0.70    1.31     0.73      0.10     0.10    1.50     0.18
  MAR         32    0.80    0.28     0.00      0.30     0.30    1.50     1.21
              33    0.80    0.41     0.13      0.80     0.80    1.48     0.00
              34    0.76    0.60     0.14      1.20     0.79    1.09     0.00
  APR         35    0.68    0.41     0.00      1.70     0.70    0.91     0.00
              36    0.79    0.48     0.00      2.20     0.35    0.62     0.00
```

Table 10. Water budget simulation for the Clark tailings with a 0.5 inch layer of applied gravel mulch for erosion control.

```
SOIL PARAMETERS:                              BOUNDARY CONDITIONS:
---------------                               -------------------

     ROOT DEPTH (CM)           = 60                SOIL WATER(0)= 3
     WATER-HOLD.CAP.(CM/CM)= .05                  SNOW(0)       = 0
     TOTAL AVAIL. WATER(CM)= 3                  DRAINAGE(0)   = 0
     WATER TABLE DEPTH (CM)= 200

SURFACE PARAMETERS:                           SIMULATION YEARLY SUMMARY:
          --------                            ------------ ------  ----

     VEG (0=NON,1=VEG)         = 0                 NOAA PPT        = 32.85
     MULCH(0=BARE,1=1CM,                           ACTUAL PPT      = 28.4964
      2=2CM,3=>4CM,4=VEG)      = 1                 TOTAL PET       = 83.6
     VEG COVER (%)             = 0                ACTUAL ET      = 25.1008
     RUNOFF CLASS   *          = 1                 AVE SOIL WATER
     SNOW TRAP EFF. (%)        = .6                 AS % RECHARGE= .843674
                                                   DRAINAGE        = 4.26877

-------------------------------------------------------------------------------
* 1=NO RUNOFF, 2=SITE WHERE RUNOFF OCCURS, 3=SITE WITH ACCUMULATION


-------------------------------------------------------------------------------
          * * *  S I M U L A T I O N   S U M M A R Y  * * *
  MONTH         I     PPT    ACT.PPT   SNOW      PET      ETa   SOIL H2O DRAINAGE
-------------------------------------------------------------------------------

                1     1.20    1.08     0.00      2.60     1.56    3.00      0.00
   MAY          2     1.37    1.23     0.00      3.60     1.58    2.52      0.00
                3     1.68    1.51     0.00      4.20     1.36    2.17      0.00
                4     2.03    2.03     0.00      4.80     1.80    2.32      0.00
   JUN          5     2.36    2.36     0.00      5.50     2.48    2.56      0.00
                6     1.72    1.72     0.00      6.00     2.46    2.43      0.00
                7     1.18    1.18     0.00      6.40     1.04    1.69      0.00
   JUL          8     0.96    0.96     0.00      6.50     1.35    1.83      0.00
                9     0.89    0.89     0.00      6.30     0.48    1.43      0.00
               10     0.72    0.72     0.00      5.80     1.23    1.84      0.00
   AUG         11     0.68    0.68     0.00      5.50     0.23    1.33      0.00
               12     0.71    0.71     0.00      4.60     0.88    1.78      0.00
               13     1.02    1.02     0.00      3.70     0.50    1.60      0.00
   SEP         14     1.21    1.21     0.00      3.20     0.99    2.13      0.00
               15     1.01    1.01     0.00      2.20     0.84    2.35      0.00
               16     0.85    0.71     0.00      1.70     0.75    2.52      0.00
   OCT         17     0.77    0.65     0.00      1.50     0.64    2.48      0.00
               18     0.75    0.63     0.00      1.20     0.52    2.49      0.00
               19     0.73    0.54     0.00      0.90     0.42    2.60      0.00
   NOV         20     0.71    0.49     0.00      0.70     0.36    2.72      0.00
               21     0.66    0.45     0.03      0.40     0.22    2.86      0.00
               22     0.61    0.26     0.07      0.00     0.00    3.00      0.09
   DEC         23     0.59    0.26     0.17      0.00     0.00    3.00      0.26
               24     0.58    0.24     0.26      0.00     0.00    3.00      0.26
               25     0.56    0.14     0.37      0.00     0.00    3.00      0.24
   JAN         26     0.54    0.18     0.56      0.00     0.00    3.00      0.14
               27     0.52    0.20     0.71      0.00     0.00    3.00      0.18
               28     0.52    0.23     0.82      0.00     0.00    3.00      0.20
   FEB         29     0.58    0.25     0.90      0.00     0.00    3.00      0.23
               30     0.61    0.27     1.00      0.00     0.00    3.00      0.25
               31     0.70    1.93     1.09      0.10     0.06    3.00      0.27
   MAR         32     0.80    0.37     0.00      0.30     0.18    3.00      1.87
               33     0.80    0.54     0.17      0.80     0.48    3.00      0.19
               34     0.76    0.75     0.18      1.20     0.72    3.00      0.06
   APR         35     0.68    0.50     0.00      1.70     1.02    3.00      0.03
               36     0.79    0.58     0.00      2.20     0.94    2.48      0.00
```

Table 11. Water budget simulation for the Clark tailings with cover soil and established vegetation.

```
SOIL PARAMETERS:                                BOUNDARY CONDITIONS:
---------------                                 ------------------

     ROOT DEPTH (CM)          = 90                     SOIL WATER(0)= 13.5
     WATER-HOLD.CAP.(CM/CM)= .15                      SNOW(0)       = 0
     TOTAL AVAIL. WATER(CM)= 13.5                      DRAINAGE(0)   = 0
     WATER TABLE DEPTH (CM)= 200
SURFACE PARAMETERS:                             SIMULATION YEARLY SUMMARY:
------------------                              -------------------------

     VEG (0=NON,1=VEG)        = 1                      NOAA PPT          = 32.85
     MULCH(0=BARE,1=1CM,                               ACTUAL PPT        = 28.4964
      2=2CM,3=>4CM,4=VEG)     = 4                      TOTAL PET         = 83.6
     VEG COVER (%)            = 80                     ACTUAL ET         = 35.8848
     RUNOFF CLASS  *          = 1                      AVE SOIL WATER
     SNOW TRAP EFF. (%)       = .6                      AS % RECHARGE= .352496
                                                       DRAINAGE          = 0

--------------------------------------------------------------------------------
* 1=NO RUNOFF, 2=SITE WHERE RUNOFF OCCURS, 3=SITE WITH ACCUMULATION


--------------------------------------------------------------------------------
           * * *  S I M U L A T I O N   S U M M A R Y  * * *
 MONTH        I     PPT    ACT.PPT   SNOW      PET       ETa    SOIL H2O DRAINAGE
--------------------------------------------------------------------------------

              1     1.20    1.08     0.00      2.60      2.60    13.50     0.00
 MAY          2     1.37    1.23     0.00      3.60      3.60    11.98     0.00
              3     1.68    1.51     0.00      4.20      4.20     9.61     0.00
              4     2.03    2.03     0.00      4.80      3.00     6.93     0.00
 JUN          5     2.36    2.36     0.00      5.50      2.97     5.95     0.00
              6     1.72    1.72     0.00      6.00      2.97     5.34     0.00
              7     1.18    1.18     0.00      6.40      2.58     4.08     0.00
 JUL          8     0.96    0.96     0.00      6.50      1.94     2.69     0.00
              9     0.89    0.89     0.00      6.30      1.43     1.70     0.00
             10     0.72    0.72     0.00      5.80      1.08     1.17     0.00
 AUG         11     0.68    0.68     0.00      5.50      0.88     0.81     0.00
             12     0.71    0.71     0.00      4.60      0.67     0.61     0.00
             13     1.02    1.02     0.00      3.70      0.55     0.65     0.00
 SEP         14     1.21    1.21     0.00      3.20      0.59     1.12     0.00
             15     1.01    1.01     0.00      2.20      0.50     1.75     0.00
             16     0.85    0.71     0.00      1.70      0.45     2.25     0.00
 OCT         17     0.77    0.65     0.00      1.50      0.43     2.51     0.00
             18     0.75    0.63     0.00      1.20      0.36     2.73     0.00
             19     0.73    0.54     0.00      0.90      0.29     3.00     0.00
 NOV         20     0.71    0.49     0.00      0.70      0.24     3.25     0.00
             21     0.66    0.45     0.03      0.40      0.14     3.50     0.00
             22     0.61    0.26     0.07      0.00      0.00     3.81     0.00
 DEC         23     0.59    0.26     0.17      0.00      0.00     4.07     0.00
             24     0.58    0.24     0.26      0.00      0.00     4.34     0.00
             25     0.56    0.14     0.37      0.00      0.00     4.58     0.00
 JAN         26     0.54    0.18     0.56      0.00      0.00     4.72     0.00
             27     0.52    0.20     0.71      0.00      0.00     4.90     0.00
             28     0.52    0.23     0.82      0.00      0.00     5.10     0.00
 FEB         29     0.58    0.25     0.90      0.00      0.00     5.33     0.00
             30     0.61    0.27     1.00      0.00      0.00     5.58     0.00
             31     0.70    1.93     1.09      0.10      0.05     5.85     0.00
 MAR         32     0.80    0.37     0.00      0.30      0.22     7.72     0.00
             33     0.80    0.54     0.17      0.80      0.61     7.87     0.00
             34     0.76    0.75     0.18      1.20      0.91     7.79     0.00
 APR         35     0.68    0.50     0.00      1.70      1.24     7.63     0.00
             36     0.79    0.58     0.00      2.20      1.37     6.89     0.00
```

Table 12. Cost of cover soil techniques for the Clark tailings at varying soil and lime costs.

COSTS SOIL $/yd	 LIME $/ton	OPTION 1 36" soil	OPTION 2 30 t lime 27" soil	OPTION 3 120 t lime 18" soil
		------------	($/acre)	------------
1	40	4800.00	*4800.00	7200.00
	40	19200.00	15[illegible]	*14400.00
1	80	*4800.00	6000.00	12000.00
4	80	19200.00	*16800.00	19200.00

* least cost option

Fertilizer rates recommended for cover soiled waste dumps would be suitable for reclaimed tailings materials.

LITERATURE CITED

Barth, R.C. and B.K. Martin. 1981. Reclamation of phytotoxic tailings. Min. and the Env. 3:55-65.

Caruccio, F.T. 1968. An evaluation of factors affecting acid mine drainage production and ground water interactions in selected areas of western Pennsylvania. p 107-155 IN Second Symp. on Coal Mine Drainage. Bituminous Coal Research

Caruccio, F.T. and G. Geidel. 1978. Geochemical factors affecting mine drainage quality. p129-148. IN F.W. Shaller and P. Sutton. Reclamation of Disturbed Lands. Amer. Soc. of Agron., Maison, WI.

Colbourn, P. 1980. Estimation of the potential oxidation rate of pyrite in coal mine spoils. Recl. Review 3:121-123.

Dacey, P.W. and P. Colbourn. 1979 An assessment of methods for the determination of pyrite in colliery spoil. Recl Review 2:113-121.

Deckler, J.H. 1982. Characterization of four inactive hardrock mines in western Montana. unpubl. M.S. thesis. Montana State University. 188p.

Farmer, E.E., B.Z. Richerdson, and R.W. Brown. 1976. Revegetation of acid mining wastes in central Idaho. US Forest Service Research Paper INT-178.

Geidel, G. 1979. Alkaline and acid production potentials of overburden: rate of release. Recl. Review 2:101-107

Hamilton, R. and W.W. Fraser. 1978. A case history of natural underwater revegetation: Mandy mine high sulfide tailings. Recl. Review 1:61-65.

Harwood, G. 1979. A guide to reclaiming small tailings ponds and dumps. US Forest Service Gen. Tech. Rpt. INT-57. 44p.

Hillel, D. 1980. Applications of Soil Physics. Acad. Press. N.Y. 385 p.

HYDROMETRICS. 1983. Summit and Deer Lodge valleys long-term environmental rehabilitation study Butte-Anaconda, Montana. Vol. VI: Silver Bow Creek. Report to Anaconda Minerals Co.

Johnson, M.S., T. McNeilly, and R.D. Putwain. 1977. Revegetation of metalifrous mine spoil contaminated by lead and zinc. Environ. Poll. 12:261-277.

Krauskopf, K.B. 1979 Introduction to Geochemistry. McGraw Hill N.Y. 617p.

Lindsay, W.L. 1979. *Chemical Equilibria in Soils* John Wiley and Sons. N.Y. 449p.

Murray, D.R. and P. Okuhura. 1980. The effect of surface treatment of tailings on effluent quality. Recl. Rev. 3:169-177.

Nielsen, R.F. and H.B. Peterson. 1972. The treatment of mine tailings to promote vegetative stabilization. Utah Agr. Expt. Stn Bulletin 485.

Parody, F.E. and W. M. Schafer. 1981. Investigation of Berkeley Pit overburden as a medium for plant growth. p385-388. IN Symp. on Surface Mining Hydrology, Sedimentology, and Reclamation. Lexington, KY.

Parr, J.F, P.B.Marsh, and J.M. Kla. 1983. *Land Treatment of Hazardous Waste*. Noyes Data Corp. Park Ridge, N.J. 423p.

Pavanasasivam, V. and J.H. Axley. 1980. Influence of flooding on the availability of soil zinc. Commun. in Soil Sci. and Plant Analysis 11:163-174.

Rogoshewski, P., H. Brown, and K. Wagner. 1983. *Remedial Action Technology for Waste Disposal Sites*. Noyes Data Corp. Park Ridge, NJ. 497 p.

Schafer, W.M. 1979. Guides for estimating cover-soil quaility and minesoil capability for use in coal stripmine reclamation in the western U.S. Recl. Review 2:67-74.

Shoemaker, H.E., E.O. McLean, and P.F. Pratt. 1961. Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminum. Soil Sci. Soc. of Amer. Proc. 19:164-167.

Singer, P.C. and W. Stumm. 1968. The kinetics of the oxidation of ferrous iron. p12-34 IN Second Symp. on Coal Mine Drainage. Bituminous Coal Research.

Smith, E.E., K.Sanks, and K. Shumate. 1968. Sulfide to sulfate reaction studies. p1-11 IN Second Symposium on Coal Mine Drainage. Bituminous Coal Research.

Sobek,A.A., W.A. Schuller, J.R. Freeman, and R.M. Smith. 1978. Field and laboratory methods applicable to overburdens and minesoils. EPA. Cincinnati, OH EPA 600/2-78-054

Wainwright, S.J. and H.W. Woolhouse. 1975. Physiological mechanisms of heavy metal tolerance in plants. p231-257. IN M.J. Chadwick and G.T. Goodman (eds) *Ecology of Resource Degradation and Renewal*. Halsted Press. NY

Wallace, A., J.W. Cha, and R.T. Mueller. 1977. Cyanide effects on transport of elements in plants. Commun. in Soil Sci. and Plant Analysis. 8:709-712.

Watkin, E.M. and J. Watkin. 1982. Tailings reclamation in eastern Canada. World Mining 1982(12):61-65.

APPENDIX G

APPENDIX G

CONVENTIONAL REVEGETATION TECHNIQUES

Conventional revegetation would follow dump removal, slope reduction or site manipulation (gouging, terracing) and on a cover soil application for all sites selected for revegetation. Liming of the upper 6-inches of waste material also may be required.

SEED MIXTURES AND RATES

Species selected for revegetation must provide effective ground cover, so several species were chosen for the variable conditions present at the waste dumps (Table A). Two separate seed mixtures were developed from the species contained in Table A, one for moderately acid cover soils (pH 5.0 to 6.0) and one for slightly acid to slightly basic cover soils with pH greater than 6 but less than 8 (Tables B and C). Both seed mixtures are more appropriate for rural sites and some modifications probably will be necessary for the more urban sites after discussions with the Butte-Silver Bow government and landowners to determine land use of the sites. For example, the Emma and Mary Louise sites are being considered for reclamation to park land.

Seeding rates are given in pounds of pure live seed (PLS) per acre. The amount of PLS per pound seed is dependent on the purity and germination rates of the species used, as purity and germination rates are always less than 100 percent.

TABLE A. SPECIES FOR VEGETATING THE BUTTE RECLAMATION SITES

Species	Preferred Variety	Seeds/lb.	Purity Germination	Soil Texture Adaptation
Grasses:				
Basin wildrye (*Elymus cinereus*)	Magnar	95,000	92/91	Medium to clay
Bluebunch wheatgrass (*Agropyron spicatum*)	Several varieties are currently being evaluated at the Texas Ave. experimental plots	117,000	88/92	Medium to clay
Canada bluegrass (*Poa compressa*)	Rubens	2,500,000	96/90	All, best on medium to clay
Hard fescue (*Festuca ovina*)	Durar	565,000	76/97	Medium to clay
Indian ricegrass (*Oryzopsis hymenoides*)	Nezpar	188,000	95/75	Sand to silt
Needle and thread grass (*Stipa comata*)		115,000	90/50	Sandy
Slender Wheatgrass (*Agropyron trachycaulum*)	Mandan	90,000	95/97	All
Streambank wheatgrass (*Agropyron riparium*)	Sodar	156,000	92/92	All, best on medium
Thickspike wheatgrass (*Agropyron dasystachyum*)	Critana	186,000	95/98	All, best on medium textures

TABLE A, Continued

Species	Preferred Variety	Seeds/lb.	Purity Germination	Soil Texture Adaptation
Grasses:				
Western wheatgrass (*Agropyron smithii*)	Rosanna	126,000	94/89	Medium to clay
Forbs:				
Cicer milkvetch (*Astragalus cicer*)	Monarch	145,000	99/96	All, best on medium to clay
Sanfoin (*Onobrychis viciaefolia*)	Eske	30,000	99/70	
Birdsfoot Trefoil (*Lotus corniculatus*)		418,000	99/99	All, best on medium to clay
Rubber rabbitbrush (*Chrysothamnus nauseosus*)		335,000	45/80	All

TABLE B. MIX 1 - SEED MIXTURE FOR MODERATELY ACID SOILS (pH 5.0- 6.0)

	Seed Mixture (Lbs. PLS/ac)		PLS*Planted/Ft^2	
Species	Drill	Broadcast	Drill	Broadcast
Basin wildrye	1.0	2.0	3	6
Canada bluegrass	0.25	0.5	12	24
Hard fescue	1.0	2.0	9	18
Indian ricegrass	3	6	9	18
Slender wheatgrass	5	10	9	18
Thickspike wheatgrass	3	6	11	22
TOTAL	13.25	26.5	53	106

* Pure Live Seed

TABLE C . MIX 2 - SEED MIXTURE FOR SLIGHTLY ACID TO SLIGHTLY BASIC SOILS (pH >6 but <8)

	Seed Mixture (Lbs. PLS/ac)		PLS*Planted/Ft^2	
Species	Drill	Broadcast	Drill	Broadcast
Bluebunch wheatgrass	1	2	2	4
Canada bluegrass	.25	.5	12	24
Needle and thread grass	1	2	3	6
Streambank wheatgrass	2	4	6	12
Thickspike wheatgrass	2	4	5	10
Western wheatgrass	2	4	2	4
Cicer milkvetch	1	2	3	6
Sanfoin	1	2	1	1
Birdsfoot trefoil	1	2	5	10
Rubber rabbitbrush	.5	1	1	2
TOTAL	11.75	23.5	40	79

* Pure Live Seed

SEED SOURCES

Only seed having the highest purity and germination rates should be used and seed should be genotypically and phenotypically similar to that of the Butte area. All seed should receive the proper scarification, stratification or innoculation process prior to delivery. Seed such as Indian ricegrass, which can be difficult to germinate until the seed coat has degenerated sufficiently, can be ordered and stored in a warm, dry place for up to two years prior to planting, thereby increasing the germination rate (Weisner, 1982, pers. comm.).

SLOPE REDUCTION

Dry conditions on waste dumps and steep slopes inhibit natural revegetation. Recontouring of waste dumps to slopes of 18 to 24 degrees or less will reduce runoff and allow the use of normal equipment for site preparation and seeding. A modified Hodder gouger can be used on slope surfaces to create numerous depressions in the soil surface. Depressions provide a suitable microclimate for plant establishment by increasing moisture availability, preventing or reducing wind and water erosion, and by providing shade (USDA-FS, 1979). The Anaconda Minerals Company has successfully used a basin blade in Butte on slopes of 22 to 24 degrees (Gordon, 1982, pers. comm.). The basin blace creates deeper basins and can be used on steeper slopes than the Hodder gauger. Slope reductions may be difficult to achieve on a number of inactive mine dumps because of immediately adjacent private property, streets or drainages.

LIME APPLICATION

Many Butte waste dump sites have acid to very acid soils with several site having pH values in the range of 2.2 to 3.3. Liming of these materials to a pH of 5.0 or greater is important to the revegetation success. Conventional liming requirement tests probably significantly underestimate the actual amount of lime necessary to maintain an acceptable pH for a number of years. Acid production from continued oxidation of sulfide minerals will lower the pH and may cause die back of established vegetation. Liming to satisfy the acid-base balance, as determined for several Butte waste dumps using a method modified from Smith, et al (1974), would probably be excessive. The rates of lime indicated by the acid base balance for the Emma and Mountain Con sites are 20 and 33 tons of lime per 1000 tons of material, respectively. Initial liming requirements for various cover soil thicknesses are summarized in the soils section and are discussed in detail in Appendix F.

FERTILIZATION OF MINE SOILS

Mine soils, waste rock and tailings are generally deficient in plant available nutrients, particularly phosphorus and nitrogen (Bradshaw and Chadwick, 1980; DePuit, 1982). Studies on mined lands in Montana show cool season perennial grasses are highly responsive to N and P fertilization (DePuit and Coenenberg, 1979; Farmer, et. al., 1974) and it can be generalized that N and P fertilization, if not essential, is at least strongly beneficial to cool season grass establishment (DePuit, 1982).

Soil fertilizer recommendations must be based on research on plot studies on representative soils. Acid tailings and waste rock being considered for reclamation in the Butte-Anaconda area are very different from most native Montana soils or even coal strip mine soils in eastern Montana. Fertilizer recommendations based on Montana Extension Service data or research done at Colstrip may not be correct. It is recommended that fertilizer trials be conducted to determine proper fertilizer application rates. Fertilizer rates, timing and placement will require further investigation for application to inactive waste dumps.

Arable soil contains anywhere from two to 60 ppm nitrate-nitrogen but this amount is subject to seasonal fluctuations (Chapman, 1965). Nitrogen availability is determined by soil organic matter content which is nearly absent in mine wastes. Generally, soils with less than 8 ppm nitrogen in the top six inches should have 40 to 50 pounds N per acre added at seeding. Supplemental nitrogen application (broadcast) of 50 to 75 pounds per acre are suggested on an annual or biennial basis until organic matter reserves accumulate in the soil. Soils with higher soil nitrogen concentrations should have decreasing amounts of pre-plant N added reaching zero N when the soil contains 20 ppm N. If grass and forb species are seeded together, nitrogen should be applied in a split application. Up to 20 pounds per acre should be applied prior to seeding to aid in grass establishment and the rest applied six to eight weeks after seedling emergence or before summer drought (Schafer, pers. comm., 1983; Calif. Fert. Assoc., 1975). While N has

been found to inhibit germination of legume species (USBM, 1974), depress forb and shrub growth and stimulate weed growth (DePuit and Coenenberg, 1979), pre-planting applications of up to 20 pounds per acre should not adversely affect germination and growth of forb and shrub species (Schafer, pers. comm., 1983).

Ammonium nitrate (34-0-0) is the preferred N source for broadcast application. Urea or anhydrous ammonia can be banded but should not be broadcast as they are subject to volitilization (Schafer, pers. comm., 1983, USDA-FS, 1979).

A Bray soil test concentration of less than 50 ppm P should have at least 50 pounds of P_2O_5 applied per acre. In very P deficient soils (less than 30 ppm Bray P), an initial application of 100 to 150 pounds P_2O_5 per acre may be beneficial as it will provide important carryover reserves of P in subsequent years. Later applications of P are neither necessary nor effective as the P cannot be incorporated where it is needed on established stands. Response of grasses to added K fertilizer is unusual on natural soils in Montana. On disturbed soils extremely low in K, initial pre-plant incorporated application of 50 pounds of K per acre is recommended (Schafer, pers. comm., 1983).

Phosphorous and potassium fertilizer should be evenly broadcast and disced into the top six inches of soil prior to seeding (Berg, 1978). It may be possible to incorporate P and K application with lime application. Only the most soluble phosphorous fertilizers (super-

phosphates and ammonium phosphate) should be used on neutral or calcareous soils (USDA-FS, 1979). On somewhat acid soils, ground rock phosphate might be a suitable P source. Rock phosphate also has some neutralizing capacity. Phosphorous availability is dependent, to a large extent, upon pH. The optimum pH for P availability is 6.0 to 7.0. Vallentine (1971) reports that maintaining a pH above 6.5, by liming, is beneficial in maximizing phosphorous availability on acid soils. Soils with a pH above 8.0 contain dominantly calcium phosphates which are relatively insoluble.

When large quantities of N and K are applied, caution should be taken not to exceed 20 pounds per acre of N plus K banded with the seed. Fertilizer guides for dryland pasture production or native range, available from the Montana Cooperative Extension Service, can be used to formulate fertilizer rates. Soil tests should be used to refine fertilizer applications at specific sites.

Table D is a general fertilization rate, assuming no available nutrients, for Butte AML sites.

TABLE D. GENERAL FERTILIZER RECOMMENDATIONS FOR BUTTE AREA INACTIVE WASTE DUMPS (Assuming no Available Nutrients)

Type	lbs/acre
Phosphorous (P_2O_5)	80-120
Nitrogen (N)	50
Potassium (K_2O)	50

MULCH

Mulch applied to a newly seeded site can prevent or inhibit erosion from water and wind, reduce evaporation of moisture from the soil surface, increase moisture infiltration and reduce seed predation by birds and small mammals (USDA-FS, 1979). Several mulch options have been tried in reclamation and include:

1) Straw mulch applied at the rate of one to three tons per acre and anchored by chemical or physical means;
2) Pelletized sewage sludge-tailings applied 1 to 1.5 inches thick on the growing surface;
3) Chemical soil stabilizers which are compatible with plant growth;
4) Hydromulching,
5) Rock, gravel or pebbles, and
6) Fabric or mats.

SEEDING METHODS

Late summer, fall and spring seeding are all widely used in reclamation. Optimum seeding time depends on the methods of seeding and mulching used. Late summer seeding can be done prior to fall rains, enabling plants to take advantage of available moisture and establish themselves prior to the first killing frost. Soil

stabilization measures would probably be necessary to protect seedings from erosion and desiccation during and after germination. Late fall seeding also can be optimum for native cool season perennial grasses. Advantages of late fall seeding include:

1) Adaptation to species with cold stratification requirements.
2) Placement of seed in soil prior to the earliest favorable germination/growth conditions in spring.
3) Minimization of seed depredation by birds and rodents.
4) Generally more favorable weather conditions for equipment operation (DePuit, 1982).

Disadvantages include soil settling and crusting, and the necessity for a soil stabilization treatment. However, mulch is desirable at these sites regardless of planting season, and mulch helps retard soil settling and crusting.

In Montana, spring seeding of cool season species should be completed by May 15 (Long, 1981). Spring seeding allows plants to take advantage of optimum moisture conditions. Access can be a major problem in the spring, as fields may only dry out enough for planting after most spring moisture is gone, and there may not be enough rain after the seed is planted to allow adequate growth before the normally dry months of July and August. Also, cold stratification requirements for some species may not be met (DePuit, 1982).

The method of seed application will be dependent upon surface conditions at the time of planting. Two conventional seeding methods, drill and broadcast seeding, are applicable in this situation. Drill seeding is accomplished on the ground, whereas broadcast seeding can be accomplished by either ground or aerial means. The small size of most of the Butte mines and waste dumps makes aerial seeding impractical.

If it is possible to get equipment on the ground, drill seeding is the preferred method of application as it uses the least amount of seed, and allows planting at specified depths. Cool season perennial grasses respond best when planted at a depth of 0.75 inches, whereas forbs and shrubs are best planted at a depth of 0.25 inches. An adequate planting depth for all recommended species would be 0.50 inches. Drill rows should be spaced six inches apart.

The seed drill should be equipped with individualized seed compartments, seed box agitator, seed metering device, furrow openers, packer wheels, and depth bands to regulate seeding depth. Notched packer wheels promote variable depth planting of forb and shrub species. Broadcast seeding should be utilized in combination with a basin blade on moderate to steep slopes (less than 24 degrees) or a modified Hodder gouger on slopes less than 20 degrees. Slope faces can be seeded with a rotary seed spreader or a mechanical seed blower. Hydroseeding would be preferred on smaller sites or where steeper slopes prevented drill seeding.

An option for revegetating steeper slopes is the use of roll mats which are layed down and anchored over seeded areas. The mats are prepared using a sprouting medium (mulch) containing seed and fertilizer sandwiched between two layers of nylon or metal mesh. The mats are anchored at the top of the face and in enough places down the dump face to provide contact between the mesh and underlying soil. Seedlings sprout in the mulch and attach themselves to available soil on the dump face. The mulch protects the seedlings from erosion and the mesh is eventually incorporated into the developing soil surface. Jute and polypropylene matting have been used to prevent erosion and aid in seedling establishment on steep slopes (slopes greater than 2h:1v) which have been seeded and fertilized. However, polypropylene matting reportedly is not as effective as jute in minimizing erosion (Swanson and Spencer, 1983, pers. comm.).

PROTECTION OF SEEDED AREAS

Once seeded, an area should be closed to all unnecessary traffic. Vehicular traffic can damage emerging vegetation and tire tracks may produce areas susceptible to erosion.

MONITORING

Revegetated areas should be evaluated by field reconnaissance during the first season following planting and areas where poor or no germination occurred should be noted. Studies can then be conducted to determine whether the cause is soil or plant related.

Establishment of a permanent, effective ground cover is of primary importance, so monitoring during the first three years should include:

1) Canopy coverage and species composition;

2) Phenology of species;

3) Factors causing reductions in growth or germination and the acreages of areas with growth inhibition;

4) Pathology and wildlife use, and

5) Methods to be used to modify any adverse environmental factors causing inhibition of germination or growth.

APPENDIX H

APPENDIX H

DETAILED COST COMPUTATIONS

COST COMPUTATIONS

Estimated costs for reclamation of abandoned mined lands in Butte are divided in three major areas:

1) Shaft protection;
2) Waste dumps, playgrounds and tailings, and
3) Open pits.

SHAFTS

Approximate costs of protecting a shaft with an opening 25 feet by 9 feet and 3000 feet deep is used as an example for each of three methods:

1) Fill the shaft with waste rock or tailings;

2) a. Concrete, 12 inches thick, reinforced, 85 feet by 100 feet cover over shaft;

   b. Rails, 120 lbs. per 3 feet, spaced 9 inches apart laid in two directions, 66 feet by 66 feet, decked with either 3/16-inch steel or planking as a cover over the shaft, and

3) Cone method using steel and concrete required that a cone be constructed of steel, fitted into a shaft and filled with concrete.

1. Backfill Shaft

Fill material must be small enough to prevent "hang-up" and enough water must be added to keep it moving downward. Tailings material is most suitable.

Cost estimate:

Given a 4-compartment shaft, rock opening 25 feet by 9 feet, 3000 feet deep

25 x 9 less timber = 179 cu. ft. per foot of shaft
= 6.63 cu. yds. per ft. of shaft

3000 x 6.63 = 19890 cu. yds to fill the shaft

@ $4.80[1] per cu. yd.............................. $ 95,472

25% contingency, and administration.................. 23,868

$ 119,340

Cost per foot of shaft = $40.00

Note: Backfill for shallow shafts (less than 1000 feet) is significantly less because of less problems with blockage. Estimated cost for shallow shafts if $3/foot (pers. comm. D. Piper, March 23, 1984).

---

[1] $4.80/cu yd includes loading and hauling from tailings pond and placement in shaft (pers. comm. D. Piper, March 23, 1984).

2a. Construct Concrete Cap

Construct 8 beam abutments @ $500 each	$ 4,000
Supply and place 4 Type-4 85' concrete beams @ $9000	36,000
Form deck (material)	10,000
Labor: 4 men 10days @ $100/day	4,000
85 x 100 reinforced slab, 315 yards @ $60/yard	19,000
Reinforcing Steel	1,000
Stripping and Clearing	$ 1,000
Sub-Total	$ 75,000
25% Contingency and Administration	$ 19,000
TOTAL	$ 94,000

2b. Rails laid in two directions, 66 ft. by 66 ft.

welded together

120 lb. used rail - @ 265/ton

Rail wt. (120 lb.) actual 132 lbs./3 feet

1452 lbs. per 33 foot rail

150 rails in each direction

150 x 2 = 300 rails

300 x 1452 - 435,600 lbs. or 217.8 tons

217.8 x $265/ton (used rail)	$ 57,700
Labor, 4 men, 10 days @ $100/day	4,000
Crane - 10 days @ $400/day	4,000
Decking 1/4" plate, 21 tons @ $300/ton	6,300
Sub-total	$ 72,000
25% contingency, engineering and administration	$ 18,000
TOTAL	$ 90,000

3. Seal shaft with cone.

Construct a 35 foot diameter 60 degree
cone with 1/4" plate steel

Excavate depression and place cone
with tip in shaft

Fill cone with concrete (lump sum).................. $145,000[1]

---

[1] Cost for a similar sized cone for a 1000 foot shaft in California (Van Dyke, 1983).

WASTE DUMPS

Dump Resloping

Costs of dump resloping are dependent on dump height, length of dump and accessibility.

For revegetation to be completed with conventional equipment, dump slopes must be reduced from angle of repose (33-38 degrees) to 22-24 degrees. The following costs of dump resloping are estimated per linear foot of dump for various dump heights.

Vertical Dump Height Ft	Volume Per Linear Foot (cu-yd)	Estimated Resloping Cost Per Foot of Dump	Estimated Additional Grading Cost Per Linear Foot of Dump	Total Cost to Regrade Slope Per Linear Foot
25	3	$0.50	$1.35	$1.85
50	11	$1.20	$2.70	$3.90
75	25	$3.30	$6.00	$9.90

Additional grading (column 4) will be required because of restrictions (houses, streets, etc) for extending dump slopes.

These costs do not include mobilization, overhead or engineering. It is expected that other finish regrading will be required in addition to dump resloping and regrading.

Some portions of sites will require a dragline rather than a crawler tractor as some waste dumps are contained by retaining walls at the toe. At these dumps, resloping must occur by moving material from the toe of the dump and placing it on top. Estimate costs of resloping these dumps are:

Dump Height (ft)	Estimated Cost of Resloping Per Linear Foot of Dump	Estimated Additional Regrading Cost Per Linear Foot of Dump	Total Cost Per Linear Foot of Dump
25	$1.85	$0.75	$2.60
50	$6.60	$2.70	$9.30

Assumes a 2½ yard bucket swing coefficient of 0.70; 50 minute hour (.83), material not hard (1.00) (Peurifoy, 1975), dragline cost @ $75/hour.

The additional regrading cost is required because a crawler tractor will be needed to grade the material moved by the dragline.

WASTE DUMP REGRADING SUMMARY

Site	Area (acres)	Est. dump Slope Footage (ft)	Dump Height (ft)	Unit Cost (yd)	Regrading Cost	Finish Grading $125/acre	Mobilization	Total
Original	4	1000	25	$2.60*	$2600	$500	$1000	$4100
Mt. Con	8	1000/500	50/25	3.90/1.85	4830	1000	1000	6830
Little Mina	1	300	50	3.90	1170	250	1000	2420
Anselmo	8	800/300	50/25	3.90/1.85	3680	1000	1000	5680
Colorado	3	700	25	2.60*	1820	500	500	2820
Buffalo	1	300	50	3.90	1170	250	500	1920
Emma	2	-	-	-	-	250	125	375
Travona	7	1500/500	25/25	1.85/260*	4080	875	1000	5955
Ophir	2	500	25	$1.85	$925	$250	$500	$1675

Note: Unit costs for regrading developed assuming D8U Crawler @ $90/hour, average operator skill (0.75), 50 minute hour (0.87), grade correction of 1.25, weight correction of 0.72 and materal not hard to cut except at dump top (1.00). Job efficiency = 0.59 - Caterpillar Performance Handbook (1982)

* Dragline cost

Topsoil Cover Haul Costs

Assume haul distance equals 2 miles from McQueen to dump sites, cycle time = 17 minutes travel, 2 minutes load, 1 minute dump = 20 minutes.

Truck capacity = 10 yards, 50 minute hour = 2½ trips @ 10 yards = 25 yards/hour.

Truck cost = $50/hour. Haul cost = $2.00/yard. Assume loading and spreading add $1.00/yard. Total cost per yard of cover material = $3.00.

Limerock Mulch Costs

Description	Units	Cost	Per Acre
Limestone for veneer	15 tons	$75/ton*	$1175
Spread limestone with sander truck	15 tons	$ 5/ton	$ 75
		TOTAL........	$1250

Gravel Mulch Costs

Load and haul gravel	15 tons	$ 6/ton	$ 90
Spread gravel with sander truck	15 tons	$ 5/ton	$ 75
		TOTAL........	$ 165

* Continental Lime Company, Townsend, Monstana (1982).

Conventional Revegetation

Assumes area has been graded and is suitable for conventional plant species. All costs per acre.

Description	Cost Range**	Average Cost
Seedbed preparation	$ 21 - 75	$ 50
Seeding costs with seed		
Drilling	120 - 140	130
Broadcast	135 - 140	140
Fertilization	122 - 175	150
Mulch	25 - 500	265
Fencing	475 - 900	700
		$ 1435
Plus 10% for Maintenance and Monitoring.........		145
	TOTAL......$	1580/acre

** Costs from Stiller and OEA (1983) and WESTECH (1984)

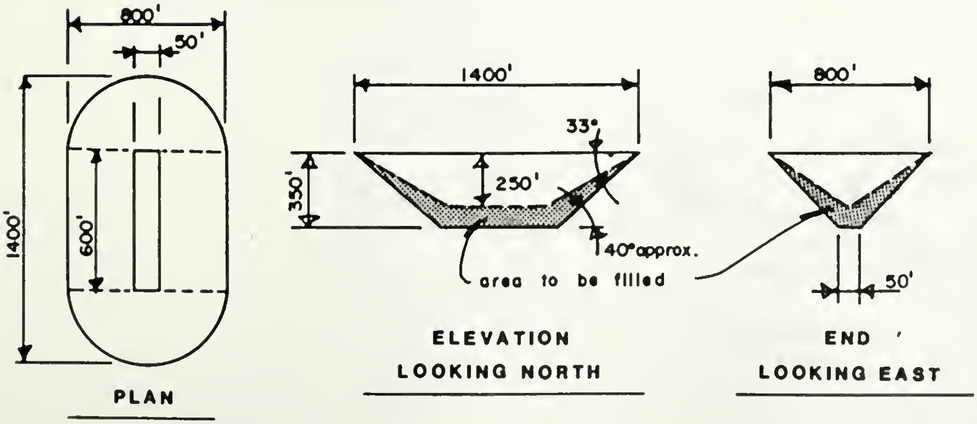
OPEN PITS

Compute volume of material required to reduce slope of pit walls from 40 to 45 degrees to angle of repose (33 degrees). Volume required equals existing pit volume minus volume of pit after backfilling.

Estimated Volume of Alice Pit

Top Dimensions - 1400 by 800 feet
Bottom Dimensions - 50 by 600 feet
Depth = 350 feet

Volume = $V_1 + V_2$



V_1 = cone = $1/3 \times 3.14 \times r^2h$ r = radius of cone h = height

$1/3 \times 3.14 \times 400^2 \times 350 = 5.9 \times 10^7\ \text{ft}^3 = 2.2 \times 10^6\ \text{yd}^3$

$V_2 = (800 + 50)/2 \times 350 \times 600/27 = 3.3 \times 10^6\ \text{yds}^3$

Estimated Existing Pit Volume = $V_1 + V_2 = \underline{5.4 \times 10^6\ \text{yds}^3}$

Volume of Pit After Filling

Top Dimensions = 1400 x 800 feet

Depth = 260 feet

$V_1 = 1/81 \times 3.14 \times r^2 \times h = 1/81 \times 3.14 \times 400^2 \times 260 = 1.6 \times 10^6\ \text{yd}^3$

$V_2 = (800 \times 260)/2 \times 600/27 = 2.3 \times 10^6\ \text{yd}^3$

Total = $1.6 + 2.3 \times 10^6 = \underline{3.9 \times 10^6\ \text{yd}^3}$

Volume of Fill Required = $5.4 \times 10^6 - 3.9 \times 10^6 = \underline{1.5 \times 10^6\ \text{yd}^3}$

Volume of Syndicate Pit

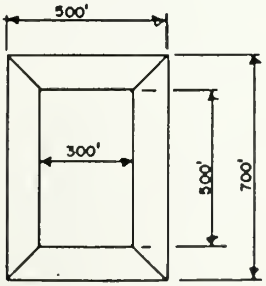
Top dimensions = 500 x 700 feet (A_1)
Bottom dimensions = 300 by 500 feet (A_2)
Depth = 100 feet (h)

Volume before filling = Frustum of Pyramid

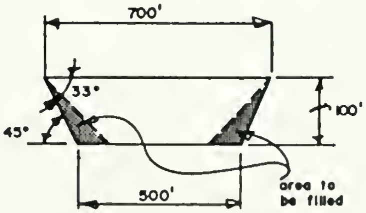
$= (A_1 + A_2 + \quad A_1\ A_2\ )\ h/3$

$= (350{,}000 + 900{,}000 + 561{,}250)\ 100/81$

$= 900{,}000\ \text{yd}^3$



PLAN



ELEVATION
LOOKING NORTHWEST

Volume after filling

Top Dimensions = 500 x 700 feet (A_1)
Bottom Dimensions = 190 x 390 feet (A_2)
Depth = 100 feet (h)

$V = (A_1 + A_2) \;+\; A_1 \; A_2 \;) \;\; 100/81 =$

$V_1 = (350{,}000 + 55{,}100 + 138{,}870) \; 100/81 = 670{,}000 \text{ yd}^3$

Volume of fill required = 900,000 - 670,000 = $\underline{230{,}000 \text{ yd}^3}$

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
		BELMONT AREA		
BELMONT	CLEAR DEBRIS AND GRADE		LUMP SUM	$2500
	CONSTRUCT 85 X 100 FT. CAP		LUMP SUM	$94000
			SUBTOTAL	$96500
OTISCO (MAIN)	DRILL TO DETERMINE SHAFT CONDITION	40 FT	$20/FT	$1000
	BACKFILL SHAFT	1000 FT	$3/FT	$3750
			SUBTOTAL	$4750
OTISCO (AIR)	BACKFILL SHAFT	100 FT	$3/FT	$375
COLORADO	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
	OPTION 1 - RESLOPE AND REGRADE		LUMP SUM	$3320
	COVER WITH 12" ALLUVIUM FROM MCQUEEN	4840 YDS	$3/YD	$18150
	AMEND WITH 30 TONS/ACRE LIME	90 TONS	$150/TON	$16875
	REVEGETATE	3 ACRES	$1600/ACRE	$6000
			OPTION 1 SUBTOTAL	$44345
	OPTION 2 - MINIMAL REGRADING		LUMP SUM	$1000
	CONSTRUCT ASPHALT DRAIN SYSTEM	700 FT	$5/FT	$4375
			OPTION 2 SUBTOTAL	$5375
HOY	EXCAVATE W/DOZER TO FIND SHAFT COND.	1 DAY	$720/DAY	$720
	BACKFILL SHAFT	200 FT	$3/FT	$750
			SUBTOTAL	$1450
HESPERUS	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	BACKFILL SHAFT	500 FT	$3/FT	$1875
			SUBTOTAL	$2875
HESPERUS AREA (UNNAMED)	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	BACKFILL SHAFT	100 FT	$3/FT	$375
			SUBTOTAL	$1375

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
MT. CON - STEWARD AREA				
PARROTT (AIR)	CLEAR DEBRIS		LUMP SUM	$1875
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$95875
ORIGINAL	CLEAN DEBRIS & GRADE		LUMP SUM	$625
	CONSTRUCT 85X100 CONC. CAP		LUMP SUM	$94000
			SUB-TOTAL	$94625
	WASTE DUMP OPTION 1			
	RESLOPE & REGRADE DUMPS		LUMP SUM	$5125
	HAUL & PLACE 12' ALLUVIUM FROM MCQUEEN	6560 YDS.	$3/YD	$24200
	AMEND WITH 30 TONS/ACRE LIME	120 TONS	$150/TON	$22500
	REVEGETATE	4	$1600/ACRE	$8000
		OPTION 1	SUB-TOTAL	$59825
	WASTE DUMP OPTION 2			
	REGRADE TO IMPROVE DRAINAGE		LUMP SUM	$1000
	CONSTRUCT ASPHALT DRAIN CURB AT DUMP CRESTS	1100 FT.	$5/FT	$6875
		OPTION 2	SUB-TOTAL	$7875
MT. CON	CLEAR DEBRIS		LUMP SUM	$10000
	CONSTRUCT 85 X 100 FT. CAP		LUMP SUM	$94000
			SUBTOTAL	$104000
	OPTION 1			
	RESLOPE AND REGRADE AREA		LUMP SUM	$8550
	COVER W/12" ALLUVIUM FROM MCQUEEN	13000 YDS	$3/YD	$48750
	AMEND WITH 30 TONS/ACRE LIME	240 TONS	$150/TON	$45000
	REVEGETATE	8 ACRES	$1600/ACRE	$16000
			SUBTOTAL	$118300
	OPTION 2			
	MINIMAL REGRADING		LUMP SUM	$2500
	CONSTRUCT DRAINAGE DIVERSION SYSTEM	2000 FT	$5/FT	$12500
			SUBTOTAL	$15000

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
	MT. CON - STEWARD AREA (CONT.)			
LITTLE MINA	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	BACKFILL SHAFT	1200 FT	$3/FT	$4500
			SUBTOTAL	$5500
	OPTION 1			
	RESLOPE DUMP		LUMP SUM	$1775
	HAUL WASTE ROCKS TO BERK. PIT	3300 YDS	$2/YD	$8250
	COVER W/12" ALLUVIUM FROM MCQUEEN	1600 YDS	$3/YD	$6000
	AMEND WITH 30 TONS/ACRE LIME	30 TONS	$150/TON	5625
	REVEGETATE	1 ACRE	$1700/ACRE	$1700
			OPTION 1 SUBTOTAL	$23350
	OPTION 2			
	MINIMAL REGRADING		LUMP SUM	$1000
	CONSTRUCT ASPHALT DRAIN CURB AT DUMP TOP	500 FT	$5/FT	$3125
			OPTION 2 SUBTOTAL	$4125
BUFFALO	CLEAR DEBRIS		LUMP SUM	$1000
	CONSTRUCT 85 X 100 FT SLAB		LUMP SUM	$94000
			SUBTOTAL	$95000
	OPTION 1 - RESLOPE AND REGRADE DUMPS		LUMP SUM	$2400
	COVER WITH 12" ALLUVIUM	1600 YDS	$3/YD	$6000
	AMEND WITH 30 TONS/ACRE LIME	30 TONS	$150/TON	$5625
	REVEGETATE	1 ACRE	$1600/ACRE	$2000
			SUBTOTAL	$16025
	OPTION 2 - MINIMAL REGRADING TO IMPROVE DRAINAGE		LUMP SUM	$500
	CONSTRUCT ASPHALT DRAIN SYSTEM	400 FT	$5/FT	$2500
			SUBTOTAL	$3000
ORIGINAL #6	BACKFILL SHAFT	550 FT	$3/FT	$2065
BENHAM	EXCAVATE SHAFT COLLAR		LUMP SUM	$500
	BACKFILL SHAFT	300 FT	$3/FT	$1125
			SUBTOTAL	$1625
STEWARD	CLEAR DEBRIS		LUMP SUM	$2000
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$96000
CLEAR GRIT	BACKFILL SHAFT	600 FT	$3/FT	$2250

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
	ANSELMO - LEXINGTON AREA			
LEXINGTON	CLEAR DEBRIS		LUMP SUM	$2000
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$96000
ANSELMO	CLEAR DEBRIS		LUMP SUM	$4000
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$98000
	OPTION 1 - RESLOPE AND REGRADE DUMPS		LUMP SUM	$5850
	COVER W/12" ALLUVIUM - 3 MI. HAUL	13000 YDS	$4/YD	$65000
	AMEND WITH 30 TONS/ACRE LIME	240 TONS	$150/TON	$45000
	REVEGETATE AREA	8 ACRES	$1600/ACRE	$16000
			SUBTOTAL	$131850
	OPTION 2 - MINIMAL REGRADING TO IMPROVE DRAINAGE		LUMP SUM	$2000
	CONSTRUCT ASPHALT DRAIN SYSTEM	1500 FT	$5/FT	$9375
			SUBTOTAL	$11375
MARQUIS	BACKFILL SHAFT	300 FT	$3/FT	$1125
WEST GAGNON	CONSTRUCT CONCRETE CAP		LUMP SUM	$94000
MISSOULA (RYAN)	BACKFILL SHAFT	500 FT	$3/FT	$1875
MISSOULA #2	BACKFILL SHAFT	100 FT	$3/FT	$375
RAVIN	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
		WALKERVILLE AREA		
RISING STAR #1	EXCAVATE SHAFT COLLAR		LUMP SUM	$ 500
	BACKFILL SHAFT	500 FT	$3/FT	$1875
			SUBTOTAL	$2375
RISING STAR (LESSEE)	EXCAVATE SHAFT COLLAR		LUMP SUM	$500
	BACKFILL SHAFT	150 FT	$3/FT	$565
			SUBTOTAL	$1065
RISING STAR (MAIN)	EXCAVATE SHAFT COLLAR		LUMP SUM	$500
	BACKFILL SHAFT	800 FT	$3/FT	$3000
			SUBTOTAL	$3500
GOLDSMITH (TONG)	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	BACKFILL SHAFT	800 FT	$3/FT	$3000
			SUBTOTAL	$4000
GOLDSMITH NONCONSOLIDATED	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	BACKFILL SHAFT	300 FT	$3/FT	$1125
			SUBTOTAL	$2125
PAYMASTER (LEASE)	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	BACKFILL SHAFT	300 FT	$3/FT	$1125
			SUBTOTAL	$2125
VENUS	EXCAVATE TO DETERMINE SHAFT COND.		LUMP SUM	$500
	HAUL MATERIAL FOR BACKFILL	1000 YDS	$1/YD	$1250
	BACKFILL SHAFT	300 FT	$3/FT	$1125
			SUBTOTAL	$2875
EVELINE	EXCAVATE TO SHAFT TO DETERMINE COND.		LUMP SUM	$500
	BACKFILL SHAFT	700 FT	$3/FT	$2625
			SUBTOTAL	$3125

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
	WALKERVILLE AREA (CONT.)			
MOOSE	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
MOOSE (AURORIA)	EXCAVATE TO SHAFT TO DETERMINE COND.		LUMP SUM	$500
	BACKFILL SHAFT	250 FT	$3/FT	$940
			SUBTOTAL	$1440
DIAMOND	CLEAR DEBRIS		LUMP SUM	$2000
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$96000
351 RAISE-MAGNA CHARTA	BACKFILL SHAFT	300 FT	$ 3/FT	$1125
WEST GRAY ROCK	CLEAR DEBRIS		LUMP SUM	$1500
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$95500
VALDEMIRE	BACKFILL	100 FT	$3/FT	$375
BELLE OF BUTTE	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	HAUL FOR BACKFILL	2500 YDS	$1/YD	$3125
	BACKFILL SHAFT	500 FT	$3/FT	$1875
			SUBTOTAL	$6000
CORRA	DRILL TO DETERMINE SHAFT COND.	40 FT	$20/FT	$1000
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$95000

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
MISCELLANEOUS AREAS				
MARY LOUISE	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
ARDSLEY BUTTE	FENCE AREA	400 FT	$12/FT	$6000
BONANZA	BACKFILL SHAFT	1000 FT	$3/FT	$3750
ANSELMO AIR	HAUL BACKFILL	4000 YDS	$1/YD	$5000
	BACKFILL SHAFT	500 FT	$3/FT	$1875
	BACKFILL AND PASS	300 FT	$3/FT	$1125
			SUBTOTAL	$8000
TRAVONA	CLEAR DEBRIS		LUMP SUM	$1500
	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
			SUBTOTAL	$95500
	OPTION 1 - RESLOPE AND REGRADE DUMPS		LUMP SUM	$5100
	COVER W/12" ALLUVIUM	11000 YDS	$3/YD	$41250
	AMEND W/LIME 30 TONS/ACRE	7 ACRES	$4500/ACRE	$39375
	REVEGETATE	7 ACRES	$1500/ACRE	$13125
			SUBTOTAL	$98850
	OPTION 2 - MINIMAL REGRADING		LUMP SUM	$1500
	CONSTRUCT ASPHALT DRAIN SYSTEM	2000 FT	$5/FT	$12500
			SUBTOTAL	$14000
OPHIR	BACKFILL SHAFT	1000 FT	$3/FT	$3750
	OPTION 1 - RESLOPE AND REGRADE AREA		LUMP SUM	$1780
	COVER W/12" ALLUVIUM - 3 MI. HAUL	3200 YDS	$4/YD	$16000
	AMEND DUMP W/30 TONS/ACRE LIME	2 ACRES	$4500/ACRE	$11250
			SUBTOTAL	$29030
	OPTION 2 - MINIMAL REGRADING		LUMP SUM	$500
	CONSTRUCT ASPHALT DRAIN SYSTEM	400 FT	$5/FT	$2500
			SUBTOTAL	$3000

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
		MISCELLANEOUS AREAS (CONT.)		
EMMA	CONSTRUCT 85 X 100 FT. CONCRETE CAP		LUMP SUM	$94000
	COVER AREA WITH 12" FILL	3200 YDS	$4/YD	$16000
	AMEND WITH 30 TONS/ACRE LIME	60 TONS	$150/TON	$9000
	REVEGETATE AREA	2 ACRES	$1500/ACRE	$3750
			SUBTOTAL	$122750
BRITANIA	DRILL TO DETERMINE SHAFT COND.		LUMP SUM	$500
	BACKFILL SHAFT	400 FT	$3/FT	$1500
			SUBTOTAL	$2000
CLARK TAILINGS	OPTION 1 - COVER WITH 12" ALLUVIUM	100000 YDS	$2/YD	$250000
	REVEGETATE	62 ACRES	$1600/ACRE	$124000
			SUBTOTAL	$374000
	OPTION 2 - COVER WITH LIMEROCK @ 15 TONS/ACRE	930 TONS	$75/TON	$87200
	OPTION 3 - COVER WITH GRAVEL MULCH @ 15 TONS/ACRE	930 TONS	$15/TON	$17500
		PLAYGROUNDS		
BASEBALL FIELD NEAR ANSELMO	COVER WITH 12" OF SUITABLE SOIL	2600 YDS	$3/YD	$9750
BASEBALL FIELD ON MISSOULA AVE	COVER WITH 12" OF SUITABLE SOIL	3400 YDS	$3/YD	$12750
PLAYGOUND SOUTH OF ALICE PIT	COVER WITH 12" OF SUITABLE SOIL	2900 YD	$3/YD	$10875

TABLE . ESTIMATED COSTS FOR BUTTE AML RECLAMATION (CONT.)

SITE	DESCRIPTION	NUMBER OF UNITS	UNIT PRICE	COST (INCLUDING 25% CONTINGENCY)
		OPEN PITS		
ALICE PIT	OPTION 1 - PARTIALLY BACKFILL PIT. ASSUME 1/3 CAN BE DOZED.	500000 YDS	$0.25/YD	$156000
	REMAINING 2/3 MUST BE HAULED 1/2 MILE.	1000000 YDS	$1.50/YD	$1875000
			SUB-TOTAL	$20310000
	OPTION 2 - FENCE PIT	4000 FT	$12/FT	$60000
SYNDICATE PIT	OPTION 1 - PARTIALLY BACKFILL PIT.	180000 YD	$1.50/YD	$337500
	OPTION 2 - REPAIR PIT PERIMETER FENCE.	4000 FT	$3/FT	$15000

REFERENCES

Caterpillar Tractor Company, 1982. Caterpillar Performance Handbook, Peoria, Illinois.

Continental Lime Company, Townsend, Montana, 1982. Personal communication to James Gillie, November 2.

Peurifoy, R. L., 1975. Estimating Construction Costs. McGraw-Hill, New York, N. Y.

Piper, D., 1984. Personal communitation with J. Gillie. March 23.

Power Crane and Shovel Association. Production Data for Power Shovels and Draglines.

State of Montana - Department of Highways, 1982. Tabulation of Low Bid Prices and Computation of Average Prices. Helena, Montana 59601. December.

Stiller, David & Associates and OEA Research, 1983. Prickley Pear Creek Abandoned Mined Lands Study. Report to Montana Department of State Lands, Helena, Montana. April.

Van Dyke, M. W., 1983. OSM's Cone Design and Installation Experience. Technical Paper at 1983 Summer Session, American Society of Agricultural Engineers, Montana State University.

WESTECH and Hydrometrics, 1982. Master Plan - Abandoned Mine Lands Reclamation, Sand Coulee and Belt Creek. Report to Montana Department of State Lands.